

THE COMPLETE FARMER

SOILS
THEIR NATURE &
TREATMENT

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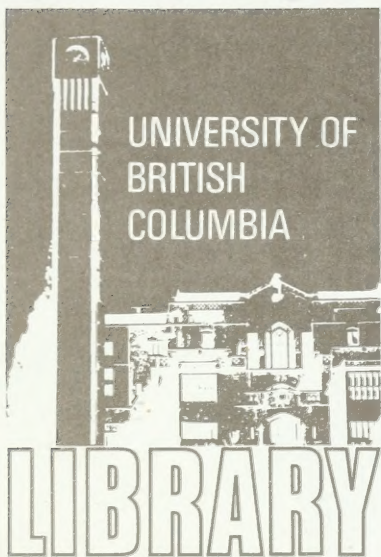
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THE COMPLETE FARMER

SOILS: THEIR NATURE
& MANAGEMENT

PRIMROSE McCONNELL

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PHOTOGRAPHIC VIEW OF A SOIL SECTION, SHOWING UNDERGROUND
LAYERS (*see page 8*).

SOILS: THEIR NATURE & MANAGEMENT

A PRACTICAL HANDBOOK

BY

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Society of Scotland, Examination Member of the Royal Agricultural
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"Agricultural Geology," "Diary of a
Working Farmer," etc. etc.*

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PREFACE

DURING the last few years the progress in the study of science applied to farming has been very great, and the number of farmers and farm students who have taken the matter up is ever on the increase.

It is believed that a summary of information on scientific practice might be usefully offered to those interested—whether young or old—hence the present series of Handbooks, of which the first is now issued. The series will consist of separate volumes on SOILS, CROPS, LIVE STOCK, DAIRY FARMING, and FARM EQUIPMENT, and each will be complete in itself. The subjects will be treated in a simple manner, without introducing many technicalities, and the volumes will form a complete treatise on modern scientific farming.

The author is himself farming extensively, and has sifted all the information through his own practical experience. In many cases farmers from long training instinctively form their judgments and ideas on anything connected with the farm without any conscious reasoning on the matter: in these volumes the scientific knowledge behind the practical work will be explained, so that the learner may understand the reasons of all the complex phenomena he meets with on a farm, and may thus in the future develop his farming on a sound scientific basis.

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SOILS: THEIR NATURE AND MANAGEMENT

CHAPTER I.—THE SOIL ITSELF

THE soil is the most important part of a farm ; therefore it naturally comes first in the estimation of a farmer, and everything in it, on it, or about it, are so many subsidiary matters which add to, or detract from, its value. Soil may be defined as the earthy matter which usually (but not always) forms the surface of the land, and which we often speak of in general terms as mould, dirt, earth, etc. It is for the soil that a farmer pays rent to the owner, and the price is usually reckoned at so much per acre—high or low according to its inherent quality and surrounding circumstances.

During the last generation or so the study of the soil itself has been very much developed and extended, and we know a great deal more about it scientifically and apply our knowledge more practically than our forefathers did. An inquiry into the subject may be conveniently grouped under (1) Origin, (2) Formation, (3) Composition, (4) Classification, (5) Distribution, (6) Fertility, and we can proceed to discuss each in turn.

I.—Origin

At one time in the history of this earth of ours, the surface of the dry land was entirely devoid of soil, and nothing was exposed on the top excepting hard rocks of various kinds. Indeed, there are many parts of the earth now—in patches in some districts, in great regions in others—where there is still no soil at all, and where, under present conditions of land, water, climate, etc., there is not likely to be in the future. The soil had an origin, and we can see with our own eyes how it originated and came to cover the greatest part

of the habitable globe, for the making of soil is going on all around us at the present day.

The origin whence every soil has been derived—with one or two exceptions which will be mentioned presently—is the rock material that comprises the crust of the earth, and the endless varieties of which give rise to corresponding variations among the soils derived from them. Rocks are composed of minerals, and minerals are in the great majority of cases definite chemical compounds, and it is from these primarily that most of our soils have been derived. There are several hundreds of kinds of minerals known and classified by mineralogists, but only about six or seven are of the first importance as the origin of soil material. These are as follows :—

Felspar, Quartz, Mica, Calcite (Limestone), Hornblende, Augite, and Kaolinite (Clay).

Felspar is the most widely distributed mineral, forming nearly half of the solid rock crust of the earth. It may be described as a double or triple silicate of alumina combined with potash, soda, or lime. Common clay is one of the products derived from it by ordinary weathering (kaolinisation). Soils which contain some undecomposed felspar in their composition have a great reserve of plant mineral food.

Quartz or silica is the hard, glassy mineral which forms the bulk of such bodies as sand, sandstone, and flint, more or less coloured by iron or other substances. It never changes in chemical composition, as the others do, from weathering. As ordinary sand it is one of the most important components of a soil, and under the microscope appears as rounded, waterworn, translucent grains. In clayey soils, however, it often occurs as “flour,” *i.e.*, exceedingly fine particles just as it was set free by the weathering of a rock.

Mica is also a double silicate of alumina with potash, magnesia, lime, or iron, but it does not easily weather down. Mica occurs as thin, shining, elastic plates, found in granite, mica-slate, etc., and it forms the small shining scales in various sandstones and soils.

Calcite is the name given to pure crystalline limestone. In one way or another lime forms the bulk of all our limestones, oolite and chalk hills, and in the weathered form is found in marl and soils. It is one of the most important components of the soil, partly from its manurial and partly from its chemical value.

Hornblende and *Augite* are silicates of lime, magnesia, and iron, without potash, soda, and alumina for the most part, and constitute the greater part of the dark green or black minerals met with in rocks. These silicates are the origin of most of the

THE SOIL ITSELF

magnesia, iron, and lime met with in ordinary soils, and, therefore, are an important source of their "inherent fertility," while the iron from these silicates is the chief colouring agent in earthy material.

Kaolinite (Clay) is really a "secondary" mineral, that is, one derived from the weathering or other modification of another mineral, principally felspar, as before mentioned. In its purest form, as kaolinite or china clay, it has the definite chemical composition of hydrated silicate of alumina ($\text{Al}_2\text{O}_3 + \text{SiO}_2 + 2\text{H}_2\text{O}$). It is sticky and plastic to handle, and the stickiness is considered to be due to the presence of a "colloid" (jelly-like) form of silicate of alumina which may be present to the extent of 1·5 per cent. When a piece of clay is dried and burnt the water of combination is driven off, its plasticity is lost and it becomes "set," or hardened, as exemplified in a burnt brick.

It is from these bodies principally that the mineral part of our soils and subsoils have been derived, and the great bulk of most every one is composed of the *débris* of these bodies.

As the surface of the globe was at one time devoid of soil, the question of age arises, and we naturally want to know *when* the soil was made. There must have been an innumerable succession of soils throughout geological time, taking the world as a whole, but for the British Islands the evidence goes to prove that at the close of the Great Ice Age, some 10,000 years ago, the wreckage left by the ice was the first material on which our soils began to be formed, and the work has been going on continuously ever since.

There is a constant washing away into the streams and out to sea of soil material, either in the shape of solid silt held in suspension in flood times, or various salts carried in solution at all times, though this wastage is being constantly renewed by the further breaking down of rock and mineral matter or the growth of vegetation. It is computed that the whole surface of the country has been lowered by about one foot in a thousand years, and as the soil still remains, and keeps approximately the same, it must be continuously renewed, and therefore no specific age can be given to it, though a limit can be fixed to the beginning of the original formation.

II.—Formation

Soil formation out of the materials before mentioned is largely a process of "weathering," but as the action of the weather is a

complicated process the different agencies comprised in the term, in addition to many other factors, had best be studied separately.

1. Water.—Assuming that we have got a fresh surface of bare rock to begin with, the first thing that happens is that it gets wet with rain. Water will soak into the hardest and closest grained rock, and this wetting leads to a number of changes. It dissolves out any soluble salts it meets with, and even some material usually considered insoluble, thus helping to loosen the mineral particles. When the rain falls in sufficient quantities it forms streams which not only help to wear off *débris* from any surface it runs over, but also carries the same downwards and deposits it elsewhere. This “rain-wash,” as it is termed, is sometimes a source of much injury to a soil already formed, for any loose material lying on sloping ground is certain to be carried downwards to the bottom of a field or into the nearest river.

Where there is no rain-wash or flooding, but only sufficient moisture to keep the materials wet, these particles accumulate on the spot and help to form the subsoil and then the soil proper in time.

The disintegrated material must accumulate somewhere, and if the surface is fairly level and there is little rain-wash, it will remain where formed. This very seldom happens, however, for the rain which helps to make it also tends to carry it downwards to the streams, especially in flood time, and thus the *débris* accumulates in the hollows, along the levels of the valleys, on places where the land is not too steep, or is carried out to sea.

This *débris* is not yet soil, however, but only its mineral matter (subsoil) and requires a lot more modification before it is fit to carry ordinary vegetation or the crops of the farm.

In connection with the action of running water is the question of the formation of soils *in situ* or by transportation of the material, and it is here necessary to correct a common erroneous impression concerning such formation. All soils have been formed where we now find them, with one or two exceptions that will be specified immediately. The eroded material (*i.e.* the subsoil) out of which the soil has been formed may have been brought from a distance—like the boulder clay, for instance—or may be native to the spot on which it is found; but the point to bear in mind is that the soil has been formed out of, and on, this material where we now find it. The only exception to this is the case of alluvial soils and others of that class, like the

"Warp-land." These have been formed mostly from the washings of soils already made higher up the streams, and so constitute "transported soils" in the proper sense of the term.

Even in an ordinary field this constant transportation is going on. If there is the slightest slope the mere action of gravity, aided by the rain in a wet time, will gradually work the finer earth downwards, and thus we find as a rule that the sandiest or stoniest part of a field is at the top and the finest soil at the bottom: in other words, the most fertile part is the lowest.

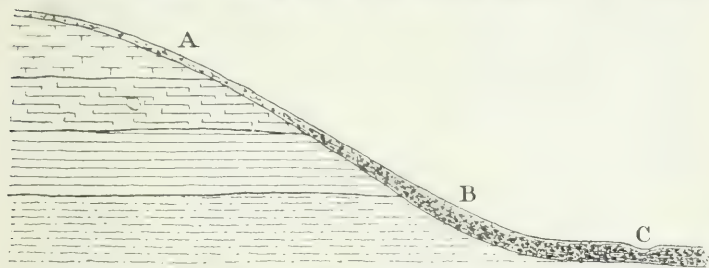


FIG. 1.—SECTION OF A HILL SHOWING POOR, THIN, STONY SOIL AT A, AND GOOD, DEEP, LOAMY SOIL AT B; STREAM AT C.

Apart from the action of the rain-wash, the soil seems to work its way bodily downwards on a sloping surface, leaving the top bare and the good soil crowded up against the bottom fence. (*See* Fig. 1.)

2. Frost.—As soon as the moisture soaks into any body it is liable to freeze on the advent of winter. Now, freezing expands the water, and thus scales, lumps, or blocks get split off and all help to swell the bulk of broken mineral.

The process may take a long time, but it is accomplished sooner or later, as we can see by the wearing away of our brick walls or old stone buildings.

Apart from the action of frost in the original manufacture of the soil, there is the effect of frost every winter on the soil already made. By freezing the moisture in the soil the particles are still further split up, lumps are broken down, the sticky action of the colloid part of the clay is temporarily checked, and when the frost departs, and the moisture dries, the soil is left in a fine, mealy or "tilthy" condition, exceedingly fit for seeding or cultivating. This process is much superior to any artificial preparation.

There is a limit, however, to the action of frost in breaking up

rock fragments and promoting the disintegration of them, and it would seem that the sand or other particles in an ordinary sample of soil have reached this limit. At any rate, the action of the frost on an ordinary soil (already formed) does not increase the *soluble* ingredients in it. The converse of the frost—the sun's heat in summer-time—has also a considerable influence. In a hot summer the ground contracts and cracks, and each crack supplies a new surface for the action of the disintegrating forces. Even the solid, rocky material is known in many cases to split up from the expansion and contraction of its material due to the change of temperature between the cold of the night time and the heat of midday. As the mineral ingredients have often different degrees of expansion, the effect of change of temperature is still more enhanced.

3. Chemical Action.—Continuously acting with the changes of temperature, etc., is the oxidising or rusting influence of the oxygen of the atmosphere. Most mineral material contains iron in its structure as one of the “cementing” constituents, and when this oxidises or “rusts,” the cementing power is destroyed and the other materials fall to pieces as an amorphous powder.

Another chemical disintegrating agent is water containing some carbonic acid gas in solution. As there is always some of this gas in the atmosphere the rain takes it up in falling, while any decaying vegetation in the surface soil will also yield some. Thus rainwater in percolating through a rock or other ground material gets charged with carbonic acid gas. Now acid-charged water has great dissolving power on minerals containing lime, potash, soda, etc., and when these bodies in the course of years dissolve out—as happens very largely with calcareous rocks—the residue again becomes broken up into earthy *débris*, thus adding to the bulk of disintegrated material.

4. Plants.—A further modification in the making of a soil is the accumulation of vegetable matter or humus in the top layer, and this begins first by the growth of the lower forms of vegetation, such as lichens and mosses. These can grow direct on a fresh rock surface and extract nutriment for themselves out of the raw mineral material and the atmosphere. The decay of these furnishes a certain amount of organic matter which mingles with the rocky *débris*, and thus the first beginnings of a soil proper are made which in time becomes fit to carry plants of a higher organisation.

When the vegetable matter accumulates in excess, so as to form the bulk of the soil, we have a peaty formation, an exception to the rule of the formation from the disintegration of mineral matter.

Peat pure and simple has mostly been formed by the growth of Mosses (*Sphagnum*, *Hypnum*, etc.), in swampy places in a cool climate, and most hollows in the districts that form the west and the north of these islands are more or less filled up with this vegetable organic humous formation.

When plants of a higher order occupy the ground their roots penetrate all crevices and fissures in the rock or soil material, and by their expanding growth split up the rock into smaller pieces, and thus promote disintegration in another way. Again the fine rootlets or root hairs secrete various "organic" acids which have the power of dissolving out the mineral food of the plants, ready for absorption by them. This is most strongly developed in lichens and mosses, and it has been shown that even in our farm crops the solving power is equal to a one per cent. solution of citric acid. Its effect can be demonstrated in the case of beans by putting earth on a polished marble slab, sowing the seed and growing some plants; when the slab is afterwards washed it will be seen that the roots ate tracks for themselves on the marble by their acid power.

5. Earthworms.—Darwin has shown that our surface soils have very largely been made, or at least, modified, by the action of the earthworms that live in them. These animals live on the vegetable matter in the soils, and to obtain it they ingest large quantities of the finer earth. This is passed through their bodies and thrown on to the surface as worm-casts, and the work of disintegration of the particles is greatly furthered by their action. They bring up this material from the lower layers, and it is computed that on an ordinary undisturbed grass field this fine material is thus deposited to the depth of one inch every five years.

In addition to this disintegration, worms are continually dragging dead leaves, straws, etc., into their burrows, and thus adding directly to the organic matter in the soil. Their burrows also are so many downward channels which help in the percolation of water, the entrance of air, and the spread of plant roots.

6. Microbes.—The soil is not the dead, inert body that it was once believed to be, but is full of living creatures, one class of which—bacterial life—is of the utmost importance in the original formation and continuous modification of its contents. A whole host of these have been isolated and described, and their life-history is now known. The transformation of plant tissue into the humic or organic portion of the soil is largely the result of microbial life. The development of various acids (such as nitric, carbonic, humic.

ulmic, etc.) is due to the action of various kinds of *Micrococci*, *Bacilli*, etc., on the humous part. These live in the top soil and as deep down as eighteen inches, and their life-work is of the utmost importance in connection with the fertility of the soil and the practice of manuring, as will be explained in the proper place. Attention is drawn here to the part they play in making the soil. Their influence is largely one of oxidation, but the acids they develop have a certain amount of "corrosive" action whereby the process of disintegration of soil material is promoted. The study of the bacterial life of the soil has developed very greatly during the last few years, and is one of the most important recent advances in the application of science to farming.

III.—Composition

Very early in the study of the soil we have to take up the question of its composition, and how the parts are put together. We may do this under five different aspects or classes : (1) Structure, (2) Proximate Constituents, (3) Organic and Inorganic parts, (4) Chemical Composition, (5) Soluble and Insoluble Ingredients.

Each of them is of course related to and dependent to some extent on the others, but each represents a separate point of view, influencing the practical farming of any particular field or piece of soil, and we may take them up in order.

1. Structure.—If we examine a section of the ground laid bare by digging where it has not been disturbed by artificial means—as on an old pasture field—we find it is composed of several layers, and these layers always occur in the same order, no matter what kind of a soil it is or in what part of the world it is found. Though in some cases one or more of the layers may be completely wanting, yet the order of occurrence always remains the same. (*See Fig. 2.*)

On the top we find first of all a grass or vegetable layer about three inches thick. It is remarkable how constant this thickness is throughout the world wherever a soil is found, and it may be looked upon as the minimum depth on which grass—the natural vegetation—will grow, as it is indeed just the thickness of a sod or a turf.

Below this comes the soil proper, from a few inches to over one foot in depth, and this, in common with the top sod, is distinguished from the lower parts by its darker colour. Next to the soil proper is the subsoil, which may be wanting altogether ;

and in other cases may extend downwards to a great depth. It is not so dark in colour as the soil proper, being often a light brown or yellow, while the soil on top is a dark brown. Below the subsoil, in the majority of cases, comes the "brash" or rubble, composed of a mixture of broken rock and subsoil.

Lowest of all is the solid rock itself, hundreds of different kinds of which are found in the world, and from these the overlying soils and subsoils take most of their characteristics.

These different layers vary in thickness, but they always occur in the same order of superposition, though some of them may be wanting, as previously stated. In a hilly or rocky district, for

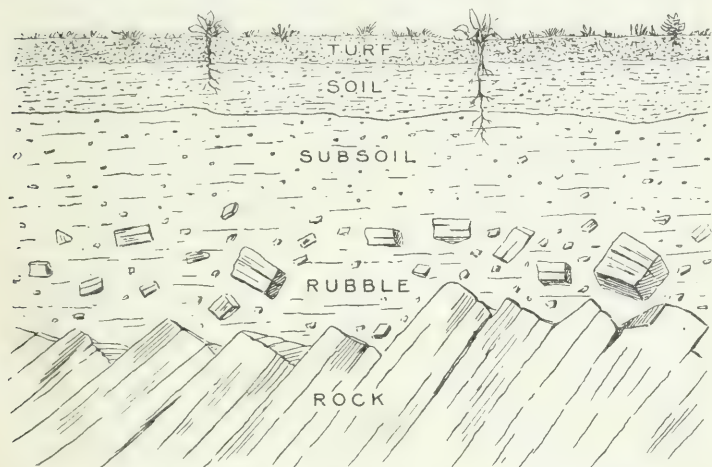


FIG. 2.—SECTION OF SOIL SHOWING UNDERGROUND LAYERS.

instance, the subsoil and the rubble may be absent and the soil rest directly on the rock, or the subsoil may be wanting and the soil overlay the rubble, and so on.

The face of the ground exposed in a quarry or railway cutting will always show some, if not all, of these component layers of the "soil," and in this connection it may be explained that in a geological sense every solid substance composing the crust of the earth is a "rock," so that in this way a clay formation may be the underlying "rock" of a district, and the subsoil and "brash" or rubble insensibly grade into this without any distinct lines of

demarcation. Sometimes, indeed, this is true of the soil itself also, and there is no visible difference between the top and the lower layers. (*See Frontispiece.*)

There is one more point connected with the structural composition of soils worthy of note, and that is the existence in some soils of a "pan" at a short distance from the surface. The continual percolation of water downwards tends to wash compounds of lime or of iron down from the top, and in the course of ages this material has been re-deposited at a depth of from six inches to a foot. It forms a sort of incrustation like a pavement in some soils, and as roots cannot penetrate through it this "pan" must be broken up by deep cultivation to improve the soil. Again, the continuous passage of the plough through the soil at one depth year after year, and the treading of the work-horses, have pasted up and consolidated a layer of soil, thus forming a "plough-pan," which also must be broken up by deeper cultivation by a farmer who intends to improve his farm.

2. Proximate Constituents.—The second method of dividing a soil into its component parts is that of its "Proximate Constituents." If a handful of soil is taken and examined by a magnifying glass, or with the naked eye, it will be found that it can in most cases be quite readily separated into various ingredients. The sand in it will be quite distinct, also the clay, the stones, etc. Systematic study has shown that the "Proximate Constituents" of all soils are five in number: sand, clay, lime, humus, and stones, and the particular varieties of these and their proportions have everything to do with the capabilities of a soil for cultivation purposes. It is indeed on the proportion of these visible components that a farmer judges of the value and usefulness of a soil as far as its mechanical condition is concerned, and it is on these that the classification of soils is founded in ordinary practice. Each of these constituents requires some explanatory remarks, which are here appended.

Sand.—Sand in the pure state is quartz or silica in small particles, and would naturally be either translucent or white from refracted light. It is usually, however, coloured red, brown, or yellow, from different oxides of iron in common with the other ingredients of the soil. It is generally found in rounded grains as the result of water wearing in bygone ages, though sometimes, when not formed of silica, it may exist as fine plates or scales (as when derived from mica).

Clay.—Clay, as mentioned before, is the hydrated silicate of

alumina. It forms the plastic, sticky part of the soil, and a preponderance of it makes the soil "heavy," that is, stiff and difficult to work. Pure clay (china clay or kaolin) is perfectly white; but that in the soil is always more or less stained by the oxides of iron, like sand. When clay is of dark or bluish grey colour it is due to the presence of sulphide of iron or to the diffusion of carbonaceous (organic) matter.

Clay differs completely in physical characteristics from sand, for whereas the latter is loose and incoherent, clay is firm, plastic and tenacious and very retentive of moisture. The particles of clay are so small that they cannot be distinguished without a microscope, $\frac{1}{5000}$ inch being the common size.

When more than one-third of the bulk of the soil is composed of clay, the soil becomes very heavy to work, requiring say three horses to the plough ("three-horse land") to do ordinary work, as it is more or less sticky, adhesive, and retentive of moisture.

Lime.—Lime in the ordinary state exists in minerals and in soils mostly as a carbonate. Every fertile soil must contain some, even if only a small percentage, while if more than four per cent. is present it becomes visible, and gives a "marly" character to the soil. It is non-plastic in its nature, and tends to make a stiff soil more crumbly and friable if present in sufficient quantity or added artificially.

Humus.—This is the general name given to the animal and vegetable matters which accumulate in the soil and mix up with the mineral ingredients. Turf may be included in the term, but for the most part it is composed of the residue of the dead roots and parts of plants which accumulate in it, and gradually change into carbonaceous matter as the result of oxidation, microbe life, etc. Peat is nearly all humus, and there is always some present in every fertile soil. It is the body that mostly gives the dark colour to the soil proper as distinguished from the subsoil.

Gravel and Stones.—Fragments of the original rock from which the soil has been derived very often form part of its bulk, and are found in the soil or lying about on its surface. These are generally angular in shape, and they constitute a continuous source from which more mineral *débris* is added to the finer parts of the soil as the weathering action proceeds. Illustrations of this occur on some of the Oolite formations of the Midlands and the Silurian districts in Galloway, where the stones consist of irregular fragments of limestone in one case and of slaty sandstone in the other. In the case of gravel the stones have been carried some distance and

have been rounded by the action of moving water, either in rivers or on the sea shore : the extensive occurrence of flint-gravel in the south-eastern half of England being the most notable example.

Some of these proximate constituents can be very easily separated from one another in a rough and ready process, which will enable one to form a better idea of the characteristics of a soil. First the soil is passed through a sieve to take out the stones and coarse particles. Next the fine part is shaken up in a glass or test tube with water and allowed to settle. The coarse grit will come down first, then the sand and finer material, and lastly the clay. These will show themselves in distinct layers in the glass or test tube, and give the experimenter a very good practical idea of the nature of the soil. It is still more instructive to compare two soils together in this way. If there is much humus present as a distinct ingredient it will partly float and partly come down as a separate layer. If some acid (say sulphuric) be poured on a quantity of the soil, there will be an effervescence of carbonic acid gas from the limestone, if present in appreciable quantity. Thus all these constituents can be identified and their quantity or proportions estimated with sufficient approximation to give a useful idea of the nature of the soil.

3. Organic and Inorganic Parts.—If a given quantity of dry soil is raised to a red heat there is a proportion of it burnt out, or driven off as carbonic acid gas. The part that burns away is termed the organic, and the solid mineral material left behind is the inorganic, part of the soil. The relative proportions of these vary very considerably in different cases. It has been explained that the organic, or humous, part of a soil is mostly the partly decayed residue of the plants and animals that have previously lived in the upper layers, which has become gradually mixed with the mineral or inorganic part. It is very largely carbonaceous in its composition, but also contains hydrogen, oxygen, and nitrogen, though not in fixed or definite proportions. There may be some carbonic acid present, of course, in various mineral carbonates (such as lime) in the soil, but in this connection it is customary to reckon all the carbon, hydrogen, oxygen, and nitrogen driven off by burning as representing so much organic material or humus.

A certain proportion of humus is desirable in a soil, because of its physical influence, but it is noteworthy that a soil may be fertile with less than one per cent. of it. On the other hand, in the case of a peaty soil, the organic part that burns away will form by far the

largest proportion, rising up to perhaps 90 per cent. of the total in some cases.

4. Chemical Composition.—When a soil is analysed by the chemist in the same way as he analyses other things he finds out the percentage proportion of its chemical ingredients. It has been discovered that all the chemical bodies necessarily met with in a soil are about a dozen in number, and while other bodies may be accidentally present, those dozen are always found in a normal soil. The following table gives their chemical names and their percentage proportions in a few typical samples:—

		<i>South.</i>	<i>Long.</i>	<i>Chap.</i>	<i>Mud.</i>	<i>Peat.</i>
Silica	SiO ₂	92.52	81.26	61.26	55.52	65.80
Alumina	Al ₂ O ₃	2.65	3.58	14.04	5.96	6.30
Ferric Oxide	Fe ₂ O ₃	3.19	3.41	4.87	5.96	6.30
Lime	CaO	.24	1.28	.83	11.15	1.01
Magnesia	MgO	.70	1.12	1.02	.25	.20
Potash	K ₂ O	.12	.80	2.80	} .071	.01
Soda	Na ₂ O	.02	1.20	1.44		
Carbonic Acid (Anhydride)	CO ₂		.92	—	8.77	—
Sulphuric Acid	SO ₃	traces	.09	.09	.04	.17
Phosphoric Acid	P ₂ O ₅	.07	.38	.24	.38	.13
Chlorine	Cl	traces	traces	.01	.76	—
Organic matter	C.H.O.N.	.49	5.96	11.25	10.50	20.08
Combined water	H ₂ O					
Nitrogen in Organic matter	N	.08	.17	.22	.20	.16

When a crop is analysed (*i.e.* a quantity of straw, grain, roots, etc.) it is found to be made up of these same substances with the solitary exception of alumina, a body sometimes, however, met with in exceptional cases, such as in lichens, etc.

The organic matter (and water) in the above is practically the same as would be driven off as gas by burning, and is composed of carbon, hydrogen, oxygen and nitrogen in various proportions. The other bodies form the bulk of the mineral or “inorganic” part. It must be clearly understood that while these bodies exist in the soil, and comprise its material, they do not occur in the simple chemical form above noted, but in an endless number of compounds. Thus, some lime and carbonic acid will be combined together to form carbonate of lime or “limestone,” some of the silica and alumina will be in the form of silicate of alumina or clay: some of the sulphur and iron as sulphide or sulphate of iron; phosphoric acid as phosphate of

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lime, and so on with endless combinations. A chemical analysis thus gives everything in its simplest chemical form, for the compound ones can with difficulty be estimated.

It will be interesting at this point to note the close connection that there is between rocks and soils, and the crops that grow on them in the nature and composition of their mineral components. This is shown in the following table :—

<i>Igneous Rocks,</i>	<i>Soils.</i>	<i>Per cent. in Soils.</i>	<i>Plant Ash.</i>
Silica	Silica	5 to 95	Silica
Alumina	Alumina	1 to 15	—
Ferric Oxide	Ferric Oxide	3 to 6	Iron
Lime	Lime	0 to 30	Lime
Potash	Potash	0 to 3	Potash
Magnesia	Magnesia	0.5 to 1.5	Magnesia
Soda	Soda	0 to 1.5	Soda
Carbonic acid	Carbonic acid	0 to 45	Carbonates
Sulphuric acid	Sulphuric acid	small	Sulphates
Phosphorus	Phosphoric acid	small	Phosphates
Chlorine	Chlorine	small	Chlorine
Manganese	Manganese	traces	Manganese
—	Bromine	traces	Bromine
—	Iodine	traces	Iodine
Fluorine	Fluorine	traces	Fluorine

It is noteworthy that recent research tends to show, however, that while a plant will be found to contain all these chemical ingredients in its composition, they do not all appear to be necessary for its growth or its health, but are absorbed by the roots out of the soil and held by the plant, as extraneous bodies, simply because it cannot help itself—for the roots suck up all soluble salts in the soil that it comes in contact with. The most important of these are seven in number : nitrogen, phosphoric acid, potash, lime, ferric oxide, magnesia and sulphuric acid. If there is a sufficiency of these present as soluble compounds the others may be left out of account as far as the crops are concerned, though they all help to form the bulk of the soil.

It can easily be understood by anyone who has the slightest knowledge of chemistry, that in a body like the soil, composed of so many chemical elements, there will probably be an endless number of chemical actions and reactions taking place. As a matter of fact the original formation of the soil and the modifications of it are really chemical actions in their ultimate effects, whether brought about by weathering, by microbe life, or by the application of

chemical manures. Unfortunately we do not yet know exactly what happens in this way in the soil, and can only conjecture from the known laws of chemical action. We are certain such changes do take place, but we can only judge of them by their practical effects on the soil and the crops it grows.

5. Soluble and Insoluble Ingredients.—If a quantity of soil is soaked in water and thoroughly mixed and stirred up for some time, a small amount of soluble salts are dissolved out. If this water is filtered off and then evaporated to dryness, the saline matter will show itself as a small quantity of white crystalline powder. This powder is the soluble part of the soil and the remainder is the insoluble. It forms a very small part of the whole, seldom reaching as much as a quarter of one per cent. of the total, though even this small quantity amounts to a lot on an acre or a field. As an inch in depth of soil equals over one hundred tons per acre it follows that in every inch in depth there may be as much as five cwt of this soluble material, or about two tons per acre in the first eight inches of depth.

This soluble material is the immediate mineral food of the plants or crops growing on the soil, and it is mainly because of its limited amount that we require to help matters by applying manures. As detailed before, however, the acid reaction of the living roots themselves enables them to dissolve out some more matter for their own direct use, so that probably double the above quantity of material is at the service of the crops. This acid reaction is reckoned as equal to a one per cent. solution of citric acid, and therefore if the soil in the above test is treated with a one per cent. solution, the resultant saline matter obtained will represent what is really available. The action of all the weathering and other agents, which helped to originally form the soil, continues to set free further portions of "soluble" material as the years go on, but the total soluble constituents remain fairly constant.

In an ordinary chemical analysis, strong acid—such as hydrochloric—is used to dissolve the materials, and in this way "soluble" matter may be obtained up to six, eight, or ten per cent., the remainder being "insoluble sand or clay," forming the bulk of the soil, but never supplying food to plants. Nowadays, however, it is usual to treat the soil with a two per cent. solution of citric acid, so as to test what is actually available and what will easily become available to the plant roots.

This soluble saline matter is chiefly composed of chlorides and sulphates of lime and soda.

IV.—Classification

For the purposes of description and discussion, soils are classified into many different kinds, and different authorities adopt different methods. The simplest method, and the one naturally adopted by practical farmers, is that first enunciated by Thaer, and we cannot very well improve on it. It is founded on the comparative proportions of the Proximate Constituents of a soil—sand, clay, humus, lime, and gravel or stones—as whichever one of these predominates it gives a distinctive character to the soil, and we thus speak of a sandy, a clayey, a humous (or peaty), etc., kind of soil. Theoretically we reckon that equal quantities of sand and clay produce a normal “loam,” but in practice anything over thirty per cent. of clay forms a stiff soil and would be called “clayey.” A clayey soil with a large proportion of lime in it (*i.e.*, over five per cent.) is called “marl,” and marly deposits have in many cases in olden times been dug up and spread on the surface of the fields to improve their fertility or texture.

Hard-and-fast percentage of the proximate constituents, however, cannot be given, because there must be endless variations of them, but every soil can be included in one or other of the following seven kinds :—

<i>Sandy.</i>	<i>Calcareous.</i>
<i>Loamy</i>	<i>Gravelly.</i>
<i>Clayey.</i>	<i>Humous.</i>
<i>Marly</i>	

While hard-and-fast percentages of the constituents of each class of soil cannot be made, we can, however, indicate the limits of such as follows :—

Sandy	Over 90 per cent.	Sand
Sandy loam	80 to 90 per cent.	Sand
Loamy	70 to 80 per cent.	Sand
Clayey loam	30 to 50 per cent.	Clay
Clayey	Over 50 per cent.	Clay
Marly	5 to 20 per cent.	Lime
Calcareous	Over 20 per cent.	Lime
Humous	Over 5 per cent.	Organic matter

Gravel or stones may form part of any of the above, and give a special character and name to them. In the same way humus (which is present in all) may be in excess in any of the above varieties and give it a corresponding character.

There may, of course, be any number of intermediate variations of these seven classes or types, but at the same time every known soil will be found to fall approximately within the limits of some one or other of them or their intermediaries.

V.—Distribution

The distribution of soils depends very largely on the geological structure of any given country or region, and in several countries the study of this distribution, and the production of soil maps, is a branch of the Geological Survey. In our own country the issue of "Drift Maps" showing surface deposits has recently been undertaken, and as these are practically soil maps everyone interested in any particular part of the country, more especially if he is looking for a farm, would be wise to procure these sheets and use with the maps of the "solid geology" of the district.

A study of these and similar maps will give one a very sound knowledge of the soils of a region, their origin and composition and characteristics, and show him what to expect before he goes to see, or may save him the trouble of going to see at all, if he is able to read a geological map. The colours and the signs on them indicate that in one district we may find the older hard rocks with rugged hills and scanty soil and exposed pastures, while in another we may find a red marl of great richness for all kinds of crops, and well sheltered, and in a third a stiff unworkable clay or a poor "hungry" sand. The limestones, clays, sandstones, grits, etc., etc., known to the geologist have each soils to correspond, but the study of these is a very wide subject, and beyond the scope of this handbook. Suffice it to say that such things as altitude, aspect, contour, water supply, rainfall and local climate depend very much indeed on the nature of the geological formations of any given district, as well as does the nature of the soil itself.

In order to show how the geological formations influence the distribution and nature of soils, the following short sketch is given beginning with the oldest and working up to the newest deposits, and indicating in general terms the prevailing character of the soil we may expect to find on each.

I.—PRIMARY FORMATIONS.

Granite.—Granite rocks generally occur as "bosses" or isolated tracts of the most rugged character. The felspar contained in them in decomposing gives rise to a clay which collects in the

hollows and is gritty from the silicious matter in the original rock. As it is generally high lying and of no extent there is little cultivation carried on, while the rocky part forms bare hills with scanty pasture, only fit to carry sheep or cattle. Met with most largely at Aberdeen, Dalbeattie, Dartmoor, and the Wicklow Mountains.

Trap.—A name given to several varieties of igneous rocks found in various parts of the country. Being composed of many different minerals they weather down into fairly fertile soils, though sometimes a little stiffish. The basaltic plateau of Antrim is a good example, while they are also met with in Skye, Mull, Renfrew, Edinburgh, and the Cheviot ranges. From these as centres, quantities of the trap rocks have been carried during the Ice Age all over the Lowlands of Scotland and the north of England, and have helped considerably in the making of the soils of these regions, and added to their fertility.

Archæan.—The oldest sedimentary rocks are the mica-slate and gneiss of the north-west of Scotland and the Western Islands. These places are of a particularly rugged and wild rocky character, with little soil to speak of, and are wholly devoted to sheep and cattle walks.

Cambrian.—This group is composed largely of slate rock and flagstone, and is met with most largely in the ruggedest parts of Wales, but is also found in the north of Scotland and south-west of Ireland. Where limestone beds occur there are patches of good soil, but usually it is thin and inferior and the districts are only fit for sheep and cattle.

Silurian.—The greater part of the Scottish Highlands, the southern districts of Scotland, part of Cumberland and Wales, the east, north and west of Ireland are all on the formations of this group. The hilly parts are in sheep walks, but on the lower parts are found good dark brown or red loamy or stony soils, often broken up with rocky spots. Some of these soils are greatly deficient in lime, which must be applied to make them productive, but they make good loamy varieties when well farmed, as exemplified in Galloway.

Old Red Sandstone.—This group of rocks gives rise to soils of the most noted fertility not only in the British Islands, but similar rocks yield good soils throughout the world. The shores of the Moray Firth, East Lothian, Hereford, Devon, and Tipperary are noted for their farming and splendid soils and crops. The soils are for the most part sandy, loamy, or marly, according to which beds predominate below them, and are always of

a rich dark red colour from the superabundance of iron oxide present.

The red soil of Dunbar, which lets at £5 per acre per annum, and grows the best potatoes in Britain, is on this group, while wheat ripens in the north of Scotland on this soil when it will fail on the adjacent Silurian and other primary rocks.

Mountain Limestone.—This forms the “backbone” of England—the range of hills running from the Borders to Staffordshire—and underlies the great central plain of Ireland, besides showing up in small pieces and strips elsewhere.

It forms a thin soil of the lighter class, but yielding a naturally sweet herbage on which sheep and cattle thrive, some of the best sheep walks in England being on this formation: sheep’s fescue grass forming a large part of the pasturage. These districts are often hilly or rocky and bare of soil, but they are noted for the quality of the mutton produced.

Millstone Grit yields a light, gritty, free-working soil, but very poor and hungry: one of the poorest sandy soils in Britain. It usually, however, forms tracts of high-lying, heathy land in central north England, and elsewhere round the edge of coal “basins,” and is mostly in sheep walks. Deficient in lime and clay.

Coal Measures.—These consist of alternate beds of shale and sandstone, and almost universally yield soils of inferior quality—poor, thin, hungry sands or else yellowish clays, according to whichever beds predominate—and therefore are inferior districts to farm in, though containing great mineral wealth. In the north of England and in Scotland they are largely overlaid by the “drift,” which, however, largely takes its character from the underlying beds.

Magnesian Limestone.—This is a deposit composed partly of the carbonate of magnesia in combination with the carbonate of lime, and occurs as a long, narrow strip running up the central part of the north of England. Magnesian limestone is not suitable for farming purposes; it yields a poor, thin, crumbly soil, carrying poor pasture and requiring high farming to make it yield good crops.

2.—SECONDARY FORMATIONS.

New Red Sandstone.—The red sandstones and marls of the Permian and Trias are very similar in character to those of the Old Red Sandstone, and almost invariably yield good red loamy or marly soils. The red soil of the Midlands is mostly on these formations, on which are some of the finest pasture lands of

England and most noted cheese-making districts—especially where the Keuper Marl comes to the surface.

Lias Clay forms a fairly rich clay soil weathering to a brown colour. Much of it is in pasture and too stiff to cultivate, flat or undulating. When drained it is the basis of some good dairy districts, as in the vales of Gloucester, Evesham, and Berkeley ; also in the dairy districts of Somerset, Gloucester, Warwick, and Leicester.

Great Oolite.—The soils of the Bath or Great Oolite yield those of a typical “brashy” nature, that is, full of angular pieces of the original (limestone) rock. They are mostly of the lighter class, and, of course, calcareous, and exceedingly suitable for sheep and barley. Fertility is moderate, but they are easily cultivated. The Cotswolds, Cleveland, and part of the Midlands are on this formation, while the beech tree is indigenous.

Oxford Clay.—One of the most extensive clay soils of England is based on this, and when joined by the Kimmeridge clay it runs from Dorset to Yorkshire, forming “The Clays.” It is difficult and expensive to work, mostly level, badly needs draining, and nearly all down in grass. Where some of these clay soils have been cultivated in bygone years the land has been left in very high crooked ridges, and it must have been very difficult and expensive to work.

Weald Clay.—This is another of the great clay formations of the country, though mostly confined to Kent. It yields a fine grained, yellowish, clay soil, very difficult to work, and very wet until drained. It forms a very flat district, and much is still in oak-forest land or natural pasture.

Gault Clay.—A strong, blue, tenacious clay soil, known in most districts as “blackland” from its dark colour. It yields good pasture, but requires much draining, liming, etc., to make into arable land.

Greensand.—The Lower Greensand is the basis of many of the unproductive sandy soils and barren heaths met with in some parts of southern England.

The Upper Greensand is the basis of one of the finest of the lighter sandy soils, especially when it mixes with the chalk marl. It yields particularly good hop and fruit soil (as at Farnham in Surrey).

Chalk.—The Lower Chalk deposit yields a thin, light soil, well adapted for barley, roots, and sheep-folding, and is mostly in cultivation. In some cases the soil is a clay formed as the residue from

chalk which has been dissolved away. Chalk Marl and Greensand make a good soil when mixed.

The Upper Chalk forms the "wolds" of Yorkshire and Lincoln, and the "Downs" met with in the south of England, famous as sheep walks: thin soil with short sweet pasture, dry and uncultivated, and covered with loose flints.

3.—TERTIARY FORMATIONS.

London Clay.—Another of the extensive clay deposits of the south of England, forming the London and the Hampshire "basins." It yields a tenacious brown or yellow soil, very expensive to work, and much in pasture, but improved by liming. When well cultivated it yields good crops of corn, but requires liming and bare-fallowing very extensively to develop it after draining.

Bagshot Sands.—Occur in patches over the London Clay as at Bagshot and Aldershot. They yield a poor, hungry, sandy or gravelly soil, mostly in heaths or copsewoods. Sometimes fairly fertile when mixed with London Clay.

4.—QUATERNARY FORMATIONS.

Boulder Clay.—A deposit left from the action of ice during the Great Ice Age. It covers large areas of the country, especially in Scotland, and is really the "formation" of such districts, and determines the nature of the soil. The Boulder Clay is a stiff impervious clay ("till") full of stones and boulders which have been derived from the rocks in the neighbourhood, and yielding a clayey soil on the top. When well farmed it is often a good cropping soil, and many of the soils of the Lowlands of Scotland and the north of England rest on it. In the south of England many of the good corn districts rest on the Great Chalky Boulder Clay, as, for example, the "Roothings" of Essex.

The Glacial Drift is reckoned of more recent age and is of a gravelly and sandy nature. Where it occurs in patches or large areas it shows a much lighter soil than Boulder Clay. Many of the gravel pits and sand pits in various parts of the country are found in this, while of course the top soil partakes of the same nature.

Brick Earth.—This only occurs in certain areas round the estuary of the Thames and on the neighbouring east coast. It may be described as a calcareous loam of exceptional natural fertility and physical texture. If the "red soil" of Dunbar (Old Red Sandstone) be classed as the most valuable for farming purposes of any in the

British Islands, then this may be put as the second best. Much of it is devoted to seed growing and market gardening purposes.

5.—RECENT FORMATIONS.

Peat.—The basis of part of the Fens ("Blacklands"), the Bog of Allen, and many of the low-lying soils in hollows in the hills in northern districts. It forms of course a typical humous soil, but is usually not very fertile till limed, clayed, etc., after draining. It is nearly all composed of the decayed or partly preserved bodies of plants which grew on the spot—mosses, heaths, etc.—and may be more or less mixed with earthy silt in parts.

Alluvium.—In a general way all the level flats along the sides of rivers, estuaries, marshes, etc., are reckoned to be deposited by the streams in flood time, and form alluvial material of various kinds. The soil is usually loamy in nature, but it may range from sand and gravel to clay, according to the nature of the deposits farther up the stream. It is thus made up of a mixture of the washings from all the other soils, and is usually the most fertile of any in its neighbourhood. The drawback is that drainage is difficult because of its levelness, while it is apt to suffer from flooding.

There is one rule with regard to the texture and composition of alluvial soils that is of interest. The stony and gravelly varieties are in the upper reaches of a stream, the sandy soils about the middle of its course, while the estuarine deposit is usually the finest silt or clay. Again, in going across a valley the stony part is next the stream, the sandy in the middle of the level stretch, and the clayey part nearest the high ground.

The above is only a very general sketch of this particular part of the subject, and details must be sought in works specially devoted to agricultural geology. Almost every little formation has its own specific soil or farming characteristics, and only a large scale geological map can give true guidance as to the special surface conditions at any spot. In this country the 1-inch maps of the Geological Survey (solid and drift) should be procured for the district in which a student or farmer is personally interested, and much valuable information bearing on the farming will be gleaned from them.

One more point is worthy of note in connection with this branch of the subject, and that is, where two formations come together the mixture is likely to make a better soil than either separately. If, for instance, a clayey district lies alongside a sandy one, then there

is likely to be a strip of loamy soil between the two, which will be more valuable than either. A marl also is better than either clay or limestone by itself, and so on with as many cases almost as we can find formations.

VI.—Fertility

Intimately connected with the composition of the soil, and indeed forming a special subject of study, is its fertility. The great bulk of most soils is composed of sand and clay with a little humus or peaty (organic) matter in them, but a soil that contains only these things is certain to be barren, and we have many examples of such throughout the world. The "proximate constituents" only form the solid basis of the soil, as it were, and serve to hold and preserve those chemical bodies which are required by plants to build up their tissues. These chemical ingredients have already been mentioned, and it is the presence of some of them in sufficient quantity and in an available state which helps to make a soil fertile, and their absence the converse. They must be present in a soluble state in the film of water which surrounds the particles of soil, though the roots of plants have themselves a certain amount of power to dissolve out the ingredients desired from raw mineral matter. These bodies exist in the soil as silicates, carbonates, phosphates, etc., and when forming part of undisintegrated mineral fragments are quite useless to plants. This explains why an analysis of a soil may show it to contain plenty of fertility, and yet it may refuse to grow crops; it is only the small percentage readily available that is of value. It has already been shown what a very small portion of a soil is soluble in water or in a weak acid, yet it is this soluble part only, and its composition, which concerns us in the question of fertility from this point of view.

Out of say seven of those chemical substances required by plants the majority are present in superabundance for growing many crops, and only three—nitrogen, phosphoric acid, and potash—are likely to become deficient. Accordingly we apply manures to replace or increase the supply of these, and therefore nearly all our elaborate applications of natural and artificial manures resolve themselves into applying various home-made or commercial combinations of these in the form of dung, compost, nitrates, phosphates, etc., as will be detailed later on.

Fertility of the soil is, however, a state of matters due to many

different factors. It is not altogether a chemical question, for the amount of the particular chemical bodies in the soil is only one item out of many bearing on the question. The physical conditions or properties of the soil as regards texture, moisture, etc. (as will be explained in the next chapter), are of the foremost importance. Conversely, a soil may be fertile as far as its composition is concerned, but from excessive dryness or excessive wetness, from closeness of texture, etc., it may refuse to grow crops.

The amount of soluble and undissolved plant food naturally in a soil is what is termed the "inherent fertility" of it, and a farmer pays rent for liberty to remove it in small annual portions in the crops and stock he sells off his farm. By adding manures he replenishes this store, and if he manures highly, he increases the stock of fertility and adds to the "cumulative fertility" of the soil and puts it into good "condition."

It is not possible, however, to make a bad soil into a good one ; to prove this statement we need only take the case of one important constituent—phosphoric acid. In an ordinary fertile soil there may be two per cent. of it present : this means, however, that in the first nine inches there will be thirty-six cwt. of this ingredient present, equivalent to, say, from five to seven tons of a phosphatic manure like superphosphate or basic slag. Now when we reflect that three cwt. to five cwt. of such manures are a common dressing per acre in practical farming, it can easily be seen how impossible it would be to make up a soil, if it happened to be naturally deficient, to the proportions of constituents such as we meet with in ordinary cases.

The development, or realisation of the fertility in a soil, again, depends very much on the farmer's management of it : on the proper cultivation, seeding, etc. ; on catching the land at the proper "tide," as it were, to do certain jobs ; on the weather, and so on ; all of which will be better understood after a perusal of the pages to follow.

The inherent capabilities of the soil can very well be judged by certain "indications" of fertility and barrenness that can quite easily be seen by anyone looking over a farm. Thus, good land will consist of gentle slopes and flats ; grow strong healthy trees, excepting beech and pines ; have good hedges ; show rich green permanent pasture with plenty of white clover ; have clover growing in the railway cuttings ; have a deep soil, reddish or dark brown in colour ; and show strong, healthy weeds—such as ragwort, thistles, bracken, etc. On the other hand, bad land will be indicated

by beech and pines being the prevailing trees ; stunted trees and hedges ; sedges, daisies, and oxeyes growing plentifully ; quaking grass, Yorkshire fog, and barren brome being common in the pastures ; soil being thin and wet or spongy underfoot ; thin wiry couch and bent grasses being common on the arable land ; and heath and moss growing plentifully.

A good crop or a bad crop may sometimes be the accident of a particular year : good land badly farmed or in a drought will show an inferior result, while poor land well farmed or in a genial season may yield a good crop for once, but the natural indications, in the shape of the trees, hedges, weeds, etc., etc., will always show the true nature of the land.

CHAPTER II.—THE PHYSICS OF THE SOIL

HAVING now got an idea of what the soil is, and how it came to be what it is, we may proceed to examine the physical characteristics and conditions which it has in common with all other bodies on the face of the earth. The soil is made up of particles of various kinds of materials, and these are subject to the ordinary laws of the physical universe in common with other forms of matter, and how these influence its farming will next engage our attention. It is best to take each branch of the subject by itself as follows :—

I.—Size of Particles

In connection with the study of the visible constituents of the soil, the size of the particles must be considered, for the texture, tenacity, and many other characteristics depend very much on this feature. Further, the predominating size of the particles has much to do with the nature and quality of the crops grown. This subject has been taken up of late years by American investigators, and some interesting facts have been elucidated. An ordinary clay soil is estimated to contain 400,000,000,000 particles per ounce, while a “good corn soil” has about 280,000,000,000 particles in the earthy part, and those experiments show that fertility and also suitability for various crops is very largely a question of fineness of particles. Thus with their refinement of “soil surveys” and methods, investigators state that soils with 250,000,000,000 to 350,000,000,000 particles per ounce are adapted for potatoes; 350,000,000,000 to 450,000,000,000 for onions, and so on. In analytical tests of soils it is customary to pass the same through a two-millimetre sieve, so as to separate the fine “earth” from the coarse stones, sand, or particles, and then to confine attention to the former. It is interesting to know the proportion this fine earth bears to the total in the different classes of soil, and below are given some typical examples in percentages by weight :—

Clayey	97
Clay Alluvium	92
Loamy	80-70
Red Sandy Loam	50-40
Sandy	30 20

It is, of course, only the clayey part that is likely to be found of the smallest size, for the grit and stones are of more measurable dimensions. In a sandy soil half of its bulk may consist of particles over $\frac{1}{1000}$ of an inch in diameter, but on the other hand, when sand is extremely fine (as "quartz flour") it approaches clay in its physical characteristics, and may actually be "cold and wet," and even plastic, where it predominates in the soil. (See Fig. 3.)

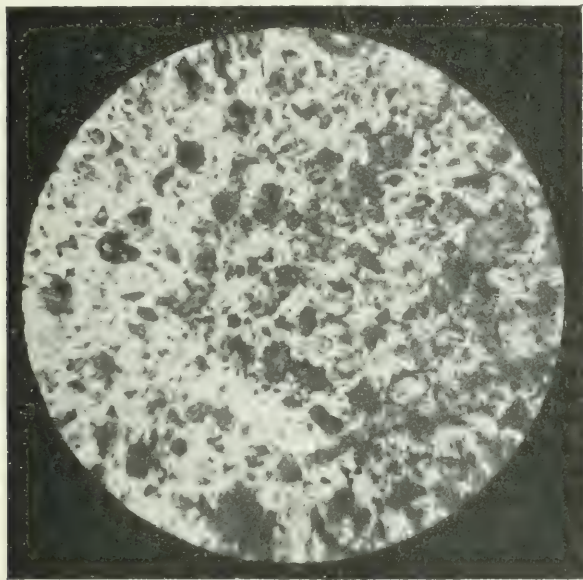


FIG. 3.—MICROSCOPIC SECTION OF ARABLE CLAY-LOAM SOIL, SHOWING PARTICLES.

In a general way, the finer the particles of a soil are the more fertile it is. This is simply because there is more surface exposed to the action of the roots than where the grains are larger, for it is in the film of water surrounding each particle that the root fibrils feed, and consequently the roots more readily get at the chemical compounds which are either in the particles or in solution in the water film. On the other hand, the finer the particles the more dense and solid is the soil as a whole, and the more in need of

cultivation and other treatment to open it up so that the roots can ramify more easily.

If the particles of a soil were all spherical and of the same size—like a boxful of marbles—the spaces between would amount to 26 per cent. of the whole bulk. If the particles were of irregular shape and size they would occupy a greater or lesser proportion of the space according to their shape and size. In an average soil the air-space occupies about 40 per cent. of its bulk, but as the particles themselves are more or less porous to water it is possible for the space occupied by water—when saturation is complete—to reach 50 per cent. of the whole, though other soils may only mount to 30 per cent.

II.—Porosity

From the fact that the soil is composed of particles we naturally conclude that there are spaces between those particles, which we term pores, and just as the size of those particles influences the farming of the soil, so, conversely, does the size of the spaces between. In common language we talk of soils being porous or dense; a sandy or gravelly soil is an example of the first and a clay of the latter state. It is necessary to explain that “porosity,” as used with reference to a soil, is not the sum of the spaces between the particles in, say, a cubic foot of soil, but the relative sizes of the spaces in different soils. For instance, clay has probably a pore space of 50 per cent. (measured by the amount of water it will hold), while a coarse sand may only have 25 to 30 per cent., yet we call the sand the more porous soil because it will allow of the freer passage of water through it. Conversely, a dense soil is one that does not allow water to pass easily—like clay.

The variation in the pore space of soils is shown in the following table:—

<i>Soils.</i>	<i>Pore Space per cent.</i>	<i>Area in sq. ft. of surface in a cub. ft.</i>
Fine Clay	52.9	173.7
Clay Soil	48.0	110.5
Loamy Clay	49.2	70.5
Loam	44.1	46.5
Sandy Loam	38.8	36.5
Sand	32.5	11.0

From the table it will be seen that in a strictly "physical" sense the clay has the greatest pore space, yet we say the sand is the most porous, because the individual spaces are larger and allow water to descend more readily.

III.—Texture

The texture of a soil is intimately connected with the proportion of Proximate Constituents present: an open texture is due to a large proportion of sand or gravel or lime, and carries with it little tenacity but much ease of cultivation, while one of close texture, due to a superabundance of clay in its composition, is accompanied with much tenacity, difficult tillage and slow percolation of water.

If more than the half of the soil is composed of clay then the texture will be decidedly tough: liable to set hard in dry weather and to crack by shrinkage into cubical masses, while in cultivation it will always tend to become cloddy or lumpy. Even if there is more than one-third part of it clay it will have a texture on the stiffish side. A moderate admixture of all the ingredients is best, and a large proportion of organic matter will improve the texture as well as anything else, and in this way a dressing of farmyard manure improves matters apart from its manurial effects, whether the texture is too close from the presence of a large proportion of clay, or too loose from much sand. Liming, again, has the effect of curdling or flocculating the colloid ingredient of a clay soil, and thus tends to make the same crumbly and friable and more easily cultivated.

Again, marling, though now seldom carried out on account of the expense, was an old method whereby light sandy soils, and even clayey ones, had their physical characteristics largely improved. Another method of improving the texture is to grow a forage crop like rape, mustard, clover, etc., and plough it in: this "green manure" will become humus in time and do much good. Where land is worked on a rotation with a grass crop grown at intervals, the ploughing down of this "lea" is also very helpful in the same way.

For temporary improvement of the texture of the soil in the way of making a tilth, however, nothing is equal to the action of frost. Whether, as some say, the frost acts on the colloid clay and congeals or flocculates it, or (what is more likely) the particles of soil are simply split apart by the expansion of the

frozen moisture between them, nothing else so improves the texture and aids the work of cultivation in making a good seed bed. This is one of the reasons why early ploughing in winter is practised as much as possible, so that the soil is turned up to the full action of the frost, and then when the dry weather of spring comes it is found to be in a loose, friable condition.

Besides the power of farmyard manure and lime in altering and improving the texture of a soil, the ordinary chemical artificial manures have also a certain effect. Thus, such manures as sulphate of ammonia, chloride of potassium, common salt, etc., have a curdling or flocculating action on the soil particles, similar to that of lime, and so make the texture freer. On the other hand, nitrate of soda has a tendency to destroy flocculation, and thus in the case of clay makes the soil stickier than before. These effects are quite separate and apart from the chemical reactions in a soil as the result of manuring.

IV.—Tenacity

The tenacity of a soil—*i.e.*, its stickiness—varies very greatly according to its texture and component parts. It is, of course, most pronounced in the case of clay and least with sand or gravel or peat, and on the degree of this depends much of the tillable ease or difficulty of cultivation. Clay is silicate of alumina, a portion of which is in a colloid or gluey state—to the extent of about 1·5 per cent. in an ordinary clay soil—and it is to this portion chiefly that the adhesive nature of the soil is due. Clay soils are thus tenacious, and resist the passage of the plough or implements of cultivation through them, and therefore they are mostly laid away in permanent pasture; they have either never been ploughed up for arable work, or they have been laid down in grass during the last twenty to thirty years, since the era of cheap corn set in, and the value of crops in general became reduced.

The difference in the tenacity of soils may be so great that one soil may require five times more force to pull a plough set at a given depth through it than is necessary in other cases, though the effect of tillage and cultivation generally is to reduce the tenacity.

When farmers talk of light and heavy soils they do not refer to the actual weight at all, but to the proportionate force required to

move the implements of tillage through the soil. Thus a sandy soil is called "light" because it is easily cultivated, and a clay soil is "heavy" because the draught to the work-horses is heavy ; in other words, it is the tenacity that is light or heavy according to the inherent texture of the soil. Thus light soils may be classed as "two-horse" lands and heavy soils as "three-horse" lands, according to the number of horses needed to pull a plough at work.

A certain amount of tenacity is necessary, because if there is none at all, from the want of a little clay (or humus), then the particles of soil will drift with the wind, and will not be capable of giving the plants roothold.

The coherence of a sandy soil is greatest when it is wet ; it will stick slightly together when damp and fall to pieces when dry. In the case of a clay the reverse holds ; it coheres least when wet, but when dry sets into a hard lump.

It is a rule not to cultivate clayey soils, if it can be avoided, when too wet, because their plastic nature causes them to "puddle" and thus the possible tilth is destroyed.

V.—Retentiveness

Improving the texture of a soil by liming it is equivalent to reducing its tenacity, and making it more workable, but on the other hand we must not forget that it is partly by its tenacity that the power of retentiveness for plant food is controlled. An open sandy soil lets the water through easily, but it also lets the elements of plant food escape as easily ; a clay holds water, but it will also hold its fertility, and any manures put on will be retained. In practical farm work this means that autumn manuring cannot be practised on light arable soils, because before spring time the rains of winter have washed all the goodness out of these manures down to the drains or deeper layers ; on a heavy soil, on the contrary, the material is retained, and putting on farmyard dung, compost, and even some classes of artificial manures, in autumn is the most desirable practice.

We can thus see that a loamy soil of medium texture and tenacity is the most desirable for mixed husbandry, on account of its medium power of retentiveness.

The retentiveness of a soil for water depends directly on its capillarity, which in turn depends on the proportion of clay or humus present. The measure of this is very well shown in the

following table, which indicates the percentage volume of water held by the different classes of soil :—

Sandy Loam	.	.	.	.	.	.	.	.	17
Loam	.	.	.	.	.	.	.	.	26
Clay Loam	.	.	.	.	.	.	.	.	28
Clay	.	.	.	.	.	.	.	.	34

These figures also exhibit very clearly comparative characteristics of various kinds, as regards the power required for plough draught, the friability of the soils, their capillarity, as well as their retentiveness for manures. Peaty or humous soil is exceptional; its corresponding percentage would be very high, but while very retentive of water or manurial matter it would not be tenacious.

The retention of manure or plant food in the soil is due partly to physical and partly to chemical action. Physically the soil acts as a filter : if some liquid manure is poured on to a quantity of earth the water that drains away below will be clear and comparatively pure, thus exemplifying the principle of sewage irrigation. The solid parts are kept back partly by the sieving action of the soil and partly by the attraction of cohesion on the surface of the soil particles, so that even the soluble salts are held mechanically in this way. For these latter, however, the retentiveness is mostly chemical, that is, some chemical reaction takes place in the soil whereby soluble salts are recombined into some compound that is less soluble. It is believed, for instance, that there are many double silicates in the soil—known as zeolites—of which the basis is silicate of alumina, but combined with some compound of lime, potash, soda, or ammonia, and that when any manurial body is put into the soil there is an immediate chemical union of its constituents with the silicates of the soil. These compounds are easily decomposable in the ordinary carbonic acid water of the soil, and the acid reaction of living roots is also sufficient to decompose them, so that there is a constant chemical action and reaction going on.

Again, the humic acid of the soil will readily unite with such bases as lime and magnesia, thus retaining them in the soil. A soluble (monobasic) phosphatic manure assumes the insoluble (tribasic) form immediately it comes into contact with lime, or iron, or alumina in the soil, and so is held in its turn till wanted by the roots of plants.

Every soil, therefore, that has a sufficient amount of clay or humus in its composition will hold—either physically or chemically—the ingredients of plant food until required by the crops. A

sandy soil is poor because it lacks the retentive components, and has thus allowed its "goodness" to be washed away, while even on fairly retentive soils a small portion of the soluble salts (especially nitrates) are continually being lost in the drains.

The retentive power of any soil is very much helped by the presence of a growing crop on it. A grass field will hold all the manure put on to it by the action of the living root fibrils, in both summer and winter. On arable fields, however, that are devoid of crops in winter, there is a great loss of fertility from the excessive downward wash of the rain where there are no living roots to keep hold of it. For this reason good practical farmers grow as many autumn-sown crops as possible ("winter" wheat, oats, barley, or beans), and some even sow "catch-crops" of clover, rape, mustard, etc., simply to occupy the ground to prevent waste of fertility, and to form a manure when eaten off by sheep or ploughed down, until the time comes round for the next regular crop to be planted.

VI.—Depth

The depth of the ordinary soil remains remarkably equal, or within certain limits, all over the world. It usually runs from three inches to over a foot, while by far the commonest depth is six to eight inches, or, in the language of the farm, it is "plough-deep," as an ordinary furrow-slice turned up with a two-horse plough usually runs from five to seven inches deep, according to the texture of the soil—extra work with three or four horses going, up to twelve inches or so if the depth and texture permits. This of course refers to the soil proper, for, as elsewhere explained, the subsoil must not be ploughed up on account of its poisonous qualities, though it may be greatly improved by stirring it to let the air enter.

This regularity in the depth of soils is wonderful: in France it runs from four to thirteen inches deep, in Germany a little less, the black loam of Russia is thin, the soils of New England are about six inches deep, the western prairies a little deeper (sometimes down to eighteen inches), in Australia from four inches to a foot, and in New Zealand four to nine inches. Some exceptional soils, as alluvium, for instance, may be much deeper than the above, but as a rule the great majority come within these limits.

Of course the difference between four and twelve inches makes a vast difference in the value of soils and in the methods of farming them. If a shallow soil is very fertile, then cropping may

be carried on successfully, but in ordinary practical farming a moderately deep soil, even if only of medium fertility, is more to be desired. One reason for this is the fact that the roots of the crops only ramify freely in the soil proper, and do not readily enter the subsoil, especially if the latter contains any raw unoxidised material. This means that in a deep soil the crop is more independent of surface conditions and is less likely to suffer from drought than on a shallow soil, while it has a greater storehouse of fertility from which to draw.

Where a soil is shallow or has not been cultivated very deeply, it may be advisable to try to improve it in this respect. Actual ploughing to a greater depth must be done very cautiously, however, for fear of bringing too much of the poisonous subsoil to the top, as where this is done the field may be injured for several years, until, in fact, the raw stuff has become meliorated into good soil.

As a rule a thin shallow soil is poorer in plant food than a deep one, because the working of the natural forces which has prevented the formation of a deep soil on a given spot, and has prevented the accumulation of plant food in it ; conversely, a deep soil is a better one.

VII.—Weight

Study of the weight of a soil brings out some surprising figures, which give us quite different ideas on various points to those we naturally expect. The actual weight of a cubic foot varies very considerably according to the composition of the soil, and whether it is stirred up by cultivation or pressed down tight and hard. The actual weights of certain selected varieties (air dried) are shown in the following table :—

<i>Soils.</i>	<i>Weight of cubic foot.</i>	<i>Specific Gravity.</i>
	lbs.	
Peaty	49	·78
Clayey	66	1·06
Loamy	76	1·22
Sandy	80	1·28

As a matter of trial pure peat may weigh as little as 30 lb., while sand may run over 100 lb. per cubic foot in the dry state, with all

sorts of intermediate varieties between, and it will thus be better understood that a clay soil is really lighter than a sandy one per cubic foot, but is called "heavy" because of its tenacity or difficulty in working. A medium ordinary arable soil in good tilth is taken at 75 lb. as a sort of standard. At this figure it will be seen that in the first nine inches of soil there are over 2,000,000 lb. of material, or to every inch in depth there is about 120 tons per acre. These figures are enormous, and show us how small an affair a top-dressing of compost or dung is compared with the bulk or weight of workable soil. If we reckon that an ordinary soil contains one-tenth per cent. of nitrogen in its composition, it yet represents at least 2,000 lb. per acre in the top soil. We thus see that when we apply a manure, which perhaps only contains 50 lb. of nitrogen per acre, it really is the merest trifle compared with the reserve stores of the soil, though it may stimulate a crop. Similar figures apply to other ingredients, and a dressing of manure at the rate of say five cwt. per acre is a small matter compared with the 1,000 tons of soil to which it is applied; the explanation of the effect is that the elements of the manure are more or less soluble and immediately available to the crops, while those in the soil are not.

Intimately connected with the weight of a soil is its specific gravity, *i.e.*, the weight compared with an equal bulk of water. In a loose, open body, full of pores and spaces like the soil, there are two kinds of specific gravity, that of the body as a whole—pores and all—and that of the materials of which it is composed. The figure that is taken, however, is that of the soil as it is, and not of the complex components of it. In the preceding table it will be seen how this varies according to the comparative weight of a cubic foot in its ordinary state, averaging about 1.2. On the other hand, if the materials were taken as solid bodies, then the average specific gravity is about 2.5, or about the same as that of the actual rock-forming minerals. To distinguish between the two it is usual to term the first figure the "apparent" and the latter the "true" specific gravity, but it is the former which is the one to be reckoned with in ordinary spade or plough work.

From these figures we can see what an enormous weight of soil we are dealing with. In ploughing a field, for instance, say only five inches deep, we are moving 600 tons of soil per acre; in levelling down a bank or cutting a drain or ditch, we may be handling as many tons: while a dressing of lime or earth, or any bulky manure, though involving much labour, is small in proportion to the bulk of the ordinary soil.

VIII.—Colour

If half-a-dozen samples of different soils are put together side by side, it will be seen that they vary very much in colour. Those soils which are extremely rich in humus, or organic matter, such as peaty and alluvial soils, will be more or less dark, perhaps actually black. Those overlying a chalk formation, where the chalk mixes with the top soil, will be whitish, or at least greyish. Those overlying the red sandstone formations are of a reddish or chocolate colour, and so on with a whole host of other variations. As a matter of fact, the colour of a soil is primarily due to the colouring matter in the rock material from which it was originally made—altered probably by oxidation, etc.—and it is often possible to follow the arrangement of the underlying formations by simply noting the changes of colour in the surface soils.

The principal colouring matters in a soil are humus and oxides of iron; if both of these were absent the soil would be white, as is the case with pipeclay and chalk. The carbonaceous matter has, of course, grown in the soil, but the iron compounds must have been in the original minerals from which the soils have been derived. In these minerals the colouring matter usually exists in some protoxide compound—yielding a light or yellow colour which it gives to the soil: as it becomes oxidised into the peroxide form it changes from red to brown, and a reddish-brown is the final colour of such soils. The process may have taken as long as the formation of the soil itself, but sometimes we can see it happening before our eyes. When a furrow-slice is freshly turned up by the plough it is often lightish brown in colour, but after a few days it has become a darker brown—the protoxide has become oxidised into the peroxide of iron.

In the case of raw clay of a bluish colour it is often sulphide of iron (Fe S_2) that is present, a salt often found in the subsoil, and poisonous to plants till it becomes oxidised into the sulphate.

As will be shown immediately, the colour of a soil immensely influences its usefulness in growing a crop on account of its effect on the temperature, and farmers always prefer one of the red or dark type.

The most desirable colour is black, and the least desirable is white, the others are intermediate. The reason for this is that black absorbs the heat of the sun most freely, while white is at the other end of the scale. As heat is one of the principal factors in making plants grow, it follows that, other things being equal,

the earliest and best crops will grow on the dark soils, and grey or white will yield late and stunted crops, a conclusion justified in actual farming. In this country peat and alluvium are often not well drained, and therefore excess of water may counteract the advantage of colour, but the growth of wheat on the prairies exemplifies what a black soil can do when other things are right.

Colour is not a thing that can be easily altered in a soil, but heavy dressings of soot, of peat, or of swamp mud help to darken it a little, while the continuous application of farmyard manure also aids not a little, apart from its manurial value.

IX.—Odour

The smell of the freshly turned-up earth is well known to every worker in the fields as one of its physical characteristics, and a few words must be devoted to it. This smell is not always the same with every kind of soil, but varies very much according to its source. If, for instance, some marshy soil be turned over the smell will be largely due to decaying vegetation, and where grass or other crop is growing the odour may be partly due to the crop. Apart from such cause, however, the ordinary earth has an odour of its own, and according to some authorities a volatile organic substance can be distilled off into water at a temperature of 140° Fah. The chemical nature of this body has not been ascertained, but it is believed to belong to the aromatic or benzene series.

The smell of a freshly turned-up furrow is reckoned one of the delightful sensations of the country, and it is not surprising to find that it is really due to the existence of a separable body in the soil.

X.—Ventilation

It may sound rather strange to the uninitiated to hear that the soil needs ventilation, but it does, and a soil that has not a sufficient supply of air is not likely to be fertile, or at best will grow stunted crops. The reason of this is that many of the chemical and bacterial processes, or changes, which take place in the soil resolve themselves into a case of oxidation, and therefore free access of the atmosphere (containing oxygen) is necessary to promote these changes.

Thus the action of the nitrifying bacteria, the oxidation of the iron in the mineral material, the conversion of plant tissue into

humus and many other changes, all require the presence of air, and these processes are expedited when the soil is broken up to admit it freely. The processes of cultivation, such as ploughing, grubbing, horse-hoeing, harrowing, etc., are largely carried out for the purpose of breaking up the soil to let the air in, and a soil in a good state of "tilth" is one that is in a well-ventilated state.

The great enemy of ventilation is stagnant water; a waterlogged soil is one with the pores full of water, so that the air has no access, and one of the objects of draining the land is that by the removal of superfluous water the air is allowed to enter into the pores between the particles.

So much does draining the land with pipe-tiles help the ventilation of the soil, that cases have occurred where the crops were immensely benefited by the work although no water ever flowed out of the drains. The soil was naturally dry, that is, it permitted the rainwater to percolate easily downwards below drain depth, but the introduction of parallel rows of pipes into the soil allowed the air access to the lower layers with decided benefit.

The air in the soil is not just the same as ordinary atmospheric air, but, amongst other things, contains a very much larger proportion of carbonic acid gas—between 3 per cent. and 15 per cent. or over. Its presence is due to the decay of the organic matter in the soil which gives off this gas, and the soil moisture absorbing it, gains much more solvent power for carbonate of lime and other minerals present.

While the removal of water by draining expedites the entrance of the air, this very air hinders for a time the free entrance of the rain from the top. Thus when a shower falls it tends to paste up the pores of the soil, preventing the egress of the air, and a thunder-storm may run off the surface because it cannot penetrate till the air has gradually escaped. After such a storm (succeeding dry weather) the soil will be heard to actually "sizzle" from the action of the escaping air.

In a state of nature, the soil ventilation is largely carried on by worms making burrows into the lower layers; by roots forcing their way through the material, dying and decaying, and so leaving a channel; and by various other methods. On the other hand, the natural plants—grass, bushes, trees—have developed themselves to suit a partially ventilated soil, but cultivated crops must have the ground stirred so that the roots may literally have air to breathe, because they have been artificially developed by cultivation. When a piece of soil becomes covered with water, or even waterlogged, the

land plants on it actually die by drowning, and their place will be taken by aquatic varieties,

XI.—Moisture

A dry soil is a barren one ; no matter how much fertility there may be in it, or how good its physical condition, it will refuse to grow crops or anything else until there is some moisture present. Much of the barren lands and “bad lands” of the Western States of America owe their barrenness to want of moisture, and when water is brought in by irrigation channels large crops of every kind can be grown.

On the other hand, however, a wet soil—that is one with the pores or spaces too full of water—is just as bad, because it is (1) cold, (2) without sufficient air for ventilation and oxidation, and (3) liable to become sour from the development of the acids known as humic, ulmic, geic, etc. Absolute waterloggedness—*i.e.*, every space and pore filled with water—only occurs at well-depth, that is if a hole is sunk in the ground until the water level is reached the top of the water as it naturally stands in this hole is the well-depth or “water-table,” below which level the ground at that spot is thoroughly full of water, and above which the water is held by the capillarity of the particles of soil in decreasing percentages until the surface is reached, where, however, it may be absolutely dry.

Water in soils is of course derived in the first place from the rain, and for the less rainy parts of the British Islands it is reckoned that of the total rainfall only one-third to one-half sinks into the soil by percolation.

1. Percolation.—This depends very much on the texture of the soil ; thus the rate differs very much in various soils. Through fine clay the water passes very slowly, while through gravel it will run quickly, and indeed the rate depends very much on the proportionate size of the particles of soil. Perhaps the extremes are clay and fissured chalk : water will pass through the chalk crevices six hundred times faster than through clay, while if the clay has been “puddled” the water will not pass through it at all. This failure of water to percolate is one of the reasons why “poaching” of land by treading it with live stock when wet, or ploughing or cultivating it in that state, spoils it temporarily for cropping purposes—the water cannot get down through it and the air is thus kept out.

The rainwater does not percolate downwards directly, but may go sideways, or zigzag as it were, following the most open channels.

It fills up the ground to complete saturation from below upwards, and keeps on gathering until an outlet is found somewhere, for instance, at a spring, or in a drain, or until it rises to the surface to form a swamp. (See Fig. 4.) As already mentioned, the surface of the "water of saturation" in the soil is known as the water-table, and is approximately the level at which the water would stand in a well. As ordinary drains are not usually put more than about three feet deep, they seldom reach the saturated area, and therefore must perform their useful work in quite another way.

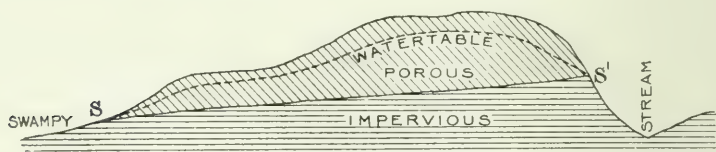


FIG. 4.—POSITION OF THE WATER-TABLE IN A HILL, AND THE OCCURRENCE OF SPRINGS (S AND S').

It is manifest that anything that "opens up" a close texture soil (such as clay) will promote the percolation of the excess of water, and therefore cultivation is the first process in this line—ploughing, grubbing, and similar work. Next comes subsoiling, and where it can be possibly carried out it is a good thing to do. The application of liberal doses of dung, apart from its manurial value, has the mechanical effect of improving the porosity and percolative power. On the other hand, when the soil is too open (as a gravel) an application of dung reduces this disadvantage, as does a dressing of earth or clay.

Liming, again, on a clay soil, by its curdling or flocculating effect, improves the percolative power.

2. Capillarity.—But water not only sinks in soils by percolation, it also rises by *Capillarity*. This action is best exhibited by taking glass tubes filled with different kinds of soil and immersing the lower ends in a vessel of water. It will be seen that after a lapse of time the water has risen—say in clay at one end of the series—to a height of fifty inches, while in coarse sand at the other end it will only rise to twenty-two inches; with other soils the rise is intermediate. Capillarity is indeed the exact opposite of percolation, and the finer the particles of soil are the higher the water rises. These two conditions combine in a clay soil to make it

"wet." The water soaks downwards with difficulty, while the upward soakage by capillarity is greatest.

The particles of soil are coated with a film of water and it is this film that has a constant tendency to spread, like oil on the surface of a pond, from its "surface tension," as it is termed. It is in this film that all the soluble salts of the soil are found and in which the roots of plants ramify, and when this dries up near the surface, as in a drought, all the processes cease. As capillarity is strongest in a clay soil, the crops suffer least on such in a drought, for moisture comes up from the store below. On the other hand, a clay suffers most in a wet season because of the excess of moisture.

This is the scientific explanation why in practice clays can be cultivated successfully in dry eastern England while they are heart-breaking soils to handle in wet districts.

It may be pertinently asked how it is that a drain removes superfluous water if it does not tap the saturated portion of the soil. The explanation is that the amount of water held by capillarity varies according to the depth. If drain depths be taken downwards and the moisture determined in percentages for each six inches, they will be found to vary in a rising (or descending) scale. Thus—

the first	6 inches will hold	.	.	16 per cent.,
the second	6 "	"	.	19 per cent.,
the third	6 "	"	.	22 per cent.,
the fourth	6 "	"	.	28 per cent.,
the fifth	6 "	"	.	40 per cent.,
the sixth	6 "	"	.	56 per cent.

The placing of a drain at this depth immediately relieves the

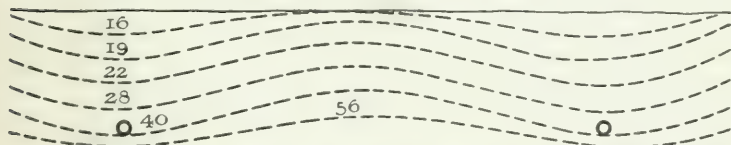


FIG. 5.—VARIATION IN THE PERCENTAGES OF CAPILLARY WATER IN THE SOIL BETWEEN TWO PIPE-TILE DRAINS.

tension, as it were, and the excess of capillary water is removed, and the remainder held in a proportion similar to that at the surface. In the space between the drains the capillarity acts as strongly as ever, and thus the soil remains damp. (See Fig. 5.) Where the drains are too far apart it is sometimes necessary to put in intermediate ones so as to reduce the capillary water between.

3. Evaporation.—When rain is not falling to increase the surface moisture, then evaporation comes into action and the moisture gradually goes off into vapour in the air. The supply is kept up by capillary action, and thus the current of water is kept moving. In this way the salts in the soil are brought into contact with the roots. Excess of this process, however, causes an efflorescence or layer of white salt on the surface, and the “alkali lands” of America are produced in this way. In this country the danger is met by the downward washing of the rainwater from time to time.

As a matter of fact the occurrence of the soil salts, or soluble part of the soil, is largely dependent upon the existence and movement of the soil water. By the upward action of capillarity they are carried to the roots of the plants or accumulated on the surface when there is a drought ; by the downward percolation of the rainwater they are washed downwards again, and in our wet climate very large quantities are washed into the drains and lost, while loose porous soils may actually become “leached” and nearly barren in this way. There is thus a constant movement of the soil water downwards, upwards, or sideways, depending altogether on the vagaries of our climate, and varying with every shower of rain or spell of fine weather.

The amount of water evaporated in a year is very great. It depends, of course, very much on the average temperature of the atmosphere of a district and on the rainfall as well ; in the south of England more than half of the rainfall returns to the air from the soil in this way, while from the surface of ponds and lakes far more is dissipated. In the neighbourhood of London over 20 inches of water is evaporated from a water surface, varying from 3·4 inches in July to ·5 inches in December.

While evaporation of the soil water is retarded by a loose layer of soil on the top, the moisture actually in the top parts is quickly dissipated by piling it up into lumps or ridges. Thus in dry districts high ridges or “balks” for root crops are a mistake—they soon dry through and through—but are suitable enough in damp districts ; while the “flat” system has to be adopted—whereby everything is on the level—where the summer rainfall is deficient.

XII.—Temperature

We are all accustomed to the fact that the temperature of the atmosphere, as measured by a thermometer, varies from day to day and from hour to hour, but it is also a fact that we have similar varia-

tions in the temperature of the soil itself, and of the air or gases in it. It is on the condition and variations of these that much of the success or failure of plant life depends. All our farm plants, and the bacteria which serve them, thrive best at temperatures between say 60° and 90° Fah., and anything above or below these figures has a tendency to check the growth of them.

The variations in the temperatures of a given soil and the different temperatures of distinct soils are largely due to the differences in the materials and colours met with. Thus a sandy, gravelly, or stony soil is always more or less "hot," and a clay more or less "cold," differences perfectly well known to farmers, and capable of being tested by the thermometer. These differences are due partly to the varying power of distinct materials to absorb the heat and thus make it "latent"—as we see in sand *versus* clay—and partly to the moisture held by the soil. A soil full of water is cold partly because the sun's heat is wasted in evaporating the water; and, conversely, a sandy soil is warm partly because of the lack of water. Farmers therefore naturally speak of a "wet, cold clay," and a "dry, warm sand," as the two types or extremes, while, of course, there are countless variations between these two.

In the case of the soil the temperature seldom goes over 150° Fah., even in hot, arid regions, and in our own "temperate" regions rarely over 100° Fah., but it may go a long way below freezing point at the other end of the scale, and anything that tends to chill it is harmful to plant growth and even to the live stock grazing on it. The sun is the source of all heat, and therefore, the top soil—like the atmosphere—is warmest in summer time, and the heat penetrates a short way downward as regards diurnal variations, but beyond this small depth it is only the seasonal variations that are noticeable.

The evaporation of moisture from the surface uses up an immense amount of the sun's heat. Indeed it is the warming up of the moisture on and near the surface that keeps damp soils cold. On a comparatively dry soil, however, the process is going on as well, so that the heat of the soil never rises too high.

In addition to the effect which moisture has on the temperature of the soil, the other great factor, as already noted, is the colour. It has been mentioned before, that the amount of heat a black substance can absorb from the sun's rays is very much more than that of a white one—taking the two extremes of colour. Thus a white and a black sand alongside of one another, and subjected

to the same conditions, showed temperatures of 104° Fah. and 129·5° Fah. respectively, a difference due solely to the colour.

In the table given below is shown the average temperature of various soils in the ordinary damp state in summer weather, from which it will be seen that the temperature variation, due partly to colour and partly to other factors, among ordinary soils may be as much as 14° Fah.

	Deg. Fah.
Peaty	86·5
Sandy	80·0
Loamy	80
Clayey	77
Chalky	73

The specific influence of the component "Proximate Constituents" no doubt has much influence on the temperature, but it will be noticed in the above table that the blackish peat has the highest temperature, and the whitish chalk the lowest. Now this variation may make all the difference between a "warm" genial *early* soil and one that is the reverse: the extra heat grows the crops much more rapidly, finer varieties can be grown, and harvest may be ten to fourteen days earlier in autumn.

The quantity of heat necessary to raise the temperature of a body one degree is called the specific heat, and in the following table the differences of the specific heats of various soils by volume are shown, taking water as 100:—

	Dry.	Wet.
Water	100	100
Peaty	30	58
Sandy Peat	21	72
Loamy	18	53
Clayey	15	61
Sandy	12·5	34

It will be noticed what a difference there is between a wet and a dry state of the soil. Also what influence its absorptive power of moisture has on the amount of heat required to warm it. It will also be seen from the table what a waste of the sun's heat there is in warming the water in the soil compared to that needed to warm the soil itself.

The average figures for medium arable soils run from 20 to 23 in the dry state: this means that if it takes 100 "units" of heat to warm up a pound of water 1° it would only require

about 20 to 23 to warm up a pound of dry soil. This is the explanation of why wet soils are "cold": the sun's heat is wasted in warming the moisture in the soil, and the soil itself is thus prevented from absorbing the heat, and the crops do not get the warmth necessary for vigorous growth, and become late and stunted. Drainage of the land, so as to remove superfluous moisture, is immediately followed by a rise in the average temperature of the soil—sometimes as much as 8° or 10° Fah.

The average temperature of the soil in England is about 1° Fah. higher than that of the atmosphere, and the average temperature of the subsoil becomes slowly higher as we descend at the rate of 1° Fah. for every fifty to sixty feet. This subterranean heat, however, has no appreciable influence on surface conditions; it is only the heat from the sun and the reception of it by the soil that concerns us as farmers.

Of course there are many other circumstances which influence the temperature of the soil and the changes in it. The aspect of a field—whether it faces the sun or away from it—is one factor, as will be detailed later on; a heavy coating of manure, if ploughed in, has been found to raise the temperature for a time as much as 3° Fah. from its fermentation, while if left on the surface it acts as a mulch by keeping the heat in and the frost out and thus promotes the growth of the grass, or other crop, in the same way as gardeners practise with fruit trees and various garden products. In like manner a coat of grass keeps the temperature up in winter by preventing the ingress of frost, so that grass land will plough for several days after the setting in of frost when bare stubble is frozen up. On the other hand, the grass prevents the ingress of heat so that the thaw takes place much more slowly than in the case of bare land, and thus the plough can be started again more quickly after frost on the latter.

The presence of stones on the surface decidedly "warms" it. A stone is a piece of solid, siliceous matter and, like sand, is easily warmed up and as easily parts with its heat to the surrounding soil in which a crop may be growing: therefore, the crop thrives more quickly. Cases have occurred where the picking of stones completely off the surface has retarded the harvest by four days. All large stones must be removed so as not to interfere with cultivation, but the smaller ones make surface "earlier" as well as more friable to work.

Even the ordinary operations of cultivation, rolling, etc., influence the temperature among other things, and is one of the ways

we can improve or control the matter by artificial means. We shall discuss this method when we come to the subject of "Tillage."

As the amount of heat received from the sun on a given square yard varies according to the season of the year, the question naturally arises how far this seasonal temperature affects the soil downwards by conduction. In general terms the daily range (between night and day) goes down three feet; the annual range (between summer and winter) penetrates 40 feet, but is felt very little beyond 25 feet down. The summer heat reaches the depth of 24 feet on January

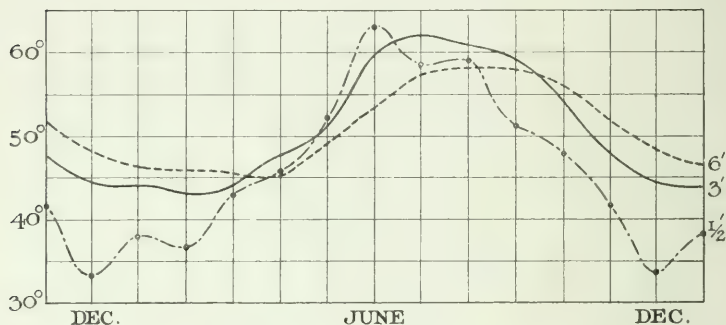


FIG. 6.—DIAGRAM OF MONTHLY SOIL TEMPERATURE AT HALF A FOOT, THREE FEET, AND SIX FEET DEEP.

4th, and the winter cold on July 13th—thus reversing the seasons. In one instance at a depth of three feet the average summer temperature was 57° Fah. and the average winter temperature 47° Fah., with many variations, as shown on diagram, but the average of the year taken as the result of many trials is shown in the following table:—

Average annual mean at 3 feet is 45·8° Fah.

"	"	"	6	"	46·1° Fah.
"	"	"	12	"	46·4° Fah.
"	"	"	24	"	46·9° Fah.

Where it is necessary to have the water supply cool, as for dairy purposes, the pipes must be buried at least three feet, therefore, as at lesser depths the water would get warmed in summer. Well water is noted for its coolness because it has the temperature of the lower layers beyond the reach of the sun.

The radiation of heat from the soil into the atmosphere is very great during the night, and begins as soon as the sun sets. This is retarded by a cloudy sky which reflects the heat back again or by

the wind which mixes up all the strata of air, and thus prevents the cold layers from settling near the ground. When, however, the sky is clear and the wind still, we have the conditions favourable for a summer frost, and in many countries abroad this is fatal in a large proportion of seasons to the crops, while even in our own country potatoes and other crops are often cut down. Anything that will prevent radiation, therefore, and keep the heat in the soil or the air directly over the soil will be of value. In practice abroad, for instance on the prairies, it is customary to light "smudge fires" with any damp rubbish so as to make a lot of smoke and vapour, and thus cloud over the crop and keep the heat in, but we have not yet done so in this country, though gardeners adopt many expedients on a small scale to this end.

XIII.—Tilth

Tilth is the condition of looseness and friability among the particles of soil necessary for the healthy growth of the crops. In its natural state in grass or woodland there is generally no tilth at all, and consequently only the natural plants of the district—grass, bushes, trees, etc.—will grow and thrive. Immediately we try to grow the cultivated crops of the farm we must cultivate the soil to suit them, because they have been developed artificially by cultivation and other treatment—some in prehistoric times like wheat, and some in recent times like the sugar beet. Cultivation in all its various forms is simply the making of a tilth in the soil to suit the seeding and the growth of the artificial plants which form our farm crops.

The making of tilth by means of the various implements of husbandry will be discussed later on, so that here it may be merely pointed out that the more we can comminute the soil, break up the lumps and mix them, the better it will be for the crop. The tendency of both the science and the practice of farming in recent years is to insist on increased tilth in the soil and to reduce the amount of manure used.

Most every soil within the top nine inches or so contains enough fertility to grow a hundred crops if it can be got into a soluble or accessible state, and the "acts of husbandry" which we carry out in tilling the soil are all for the purpose of pulverising, mixing, aerating and otherwise making what we call good tilth, so as to either set free the elements of fertility, or at least open up the soil so that they may be available for the roots of the crops.

It has been abundantly shown by experience that a rich soil will

not grow good crops without proper cultivation, while an inferior one will often grow fairly good crops if the tilth is all that it should be. It has also been shown that manures will not force a crop to grow where the cultivation is deficient.

Everything therefore points to the fact that in the growth of the artificial plants, which constitute our farm crops, tilth comes first, fertility of the soil second, and manuring third, and the modern tendency is to cultivate more and manure less—a system which, seemingly paradoxical, does not impoverish the soil.

One of the primary practical uses of good tilth is to supply a proper seed bed. It is important with all young seedling plants to give them a good start in life, as it were, for if stunted in the critical early stages nothing will make up afterwards for the damage done. The production of a loose, mellow, friable surface is particularly desirable for a seed bed, and for this reason early tillage is necessary. When the soil has been ploughed or otherwise cultivated in sufficient time to permit of the action of the weather—and particularly that of frost—on it, then it falls into a nice mealy state very suitable for further tillage in the spring time. If, on the other hand, the cultivation is done late, and especially if the soil is wet, then we have the formation of clods, and the soil is left lumpy, and it may take a whole season to cure this, while the crop suffers accordingly.

Frost is the great producer of tilth, and nothing done by implements and any amount of labour can equal the effect of it. The expansion of the moisture in freezing breaks open the lumps, clods, and pieces of soil in a way that nothing else can do. To get the full benefit of frost, however, it is necessary to have the ploughing done in the autumn and early winter, and therefore good farmers always try to have this work well forward.

As a rule the formation of a tilth is confined to the top soil. There are reasons why we sometimes do not want it to penetrate too deeply, but prefer to have the lower layers firm and moist after cultivation, rather than loose and friable, in a dry district or a dry season, as will be immediately shown.

A fine mealy surface, however, is generally desirable, and hand and horse hoeing are employed to produce this condition. When a soil is in a very fine state of tilth and heavy rain falls, the particles are apt to “run” together, and the condition known as “soil capping” results. This state is very detrimental to the crops, and in the case of root crops hand and horse hoeing must be carried on as soon as the soil is again dry enough. To prevent this tendency as much as possible, the tilth must not be too fine, while the trouble

varies according to the kind of soil, being worst on one of a clayey texture and least on a sandy one. A soil deficient in tilth, or which has become "capped," is very liable to crack and leave great fissures in dry weather—especially in clay soils—and surface cultivation must follow to prevent or cure this.

A few words are necessary to explain the physical effects of tilth on the soil itself. First, the surface cultivation prevents excessive loss of water from evaporation in dry seasons, and enables the roots of the crop to get more moisture. When the top inch or two of soil is loose the capillary power is destroyed, and therefore the soil water is not raised to the top to be lost by evaporation, but remains just under the loose "mulch" where the roots get it, so that in this way the water contents of the top soil are increased.

In a wet season or in a wet district no attention need be paid to this, but in the dry eastern counties of England this system has to be followed to make turnip and mangold growing a success, and the crops are grown "on the flat," and not on ridges, so as to get the fibrils nearer to the soil moisture, and thus conserve the water.

Even the temperature of the soil is raised a degree or two where well tilled: there is no waste of heat in evaporation of the moisture in a dry time, while when the soil is wet it is more quickly dried by the wind if stirred up, and it thus gets sooner warmed again.

CHAPTER III.—THE PHYSICAL GEOGRAPHY OF THE FARM

WE have seen what the soil of a farm is and what takes place in it, as it were, when we cultivate and grow crops upon it. We have now to see how circumstances and the surrounding conditions affect a farm, and influence its power to grow crops and pay rent. These are for the most part outside the farm itself, or at least affect a whole countryside together. For purposes of systematic study they may be grouped under (1) Latitude, (2) Altitude, (3) Climate, (4) Rainfall and Water Supply, (5) Shelter, (6) Aspect, (7) Contour, (8) Sea Influence, (9) Natural Vegetation.

I.—Latitude

It is of course a matter of common knowledge that there is a very great difference between the climate of the north of Scotland and that of the south of England—to take the two extremes of the British Islands. The explanation of this is that the one is nearer to the north than the other, and therefore is subjected to a lower average temperature, to a greater amount of stormy weather, and of frost and snow, while the day will be excessively short in midwinter for doing the work. Many other subsidiary matters influence these phenomena, as will be explained in this chapter, but the general fact remains that given two farms, alike in other respects, the northern is worth less rent than the southern one, for the farming and the cropping must be greatly influenced by these things, while the conditions of life generally are more desirable in the south than in the north.

Isothermals.—If the average temperature of the atmosphere is taken for various districts all over the country and a line be drawn connecting those of the same figure, that line is termed an “isothermal.” It is found that for the British Islands these lines run from north-west to south-east across the country, and that the line for the south-east of England is 64° Fah. and for the north-west of Scotland 54° Fah., a difference of 10° Fah. in favour of the average conditions in the south. These ten degrees have a tremendous effect on

the kinds and qualities of the crops grown. Besides these isothermals due to difference of latitude, there is the temperature of east *versus* west; the east coast is always 2° colder than the west. The sea equalises the heat at the shore all round our coast, but the east is colder than the west all the same.

II.—Altitude

It is pretty well known that one of the factors which influence the climate in general, and any farm in particular, is the height above sea-level. On the seashore there may never be any appreciable frost and snow at all, while a few miles inland, but up among the hills, the winters may be long and severe, and snow may lie deep and late. This difference may not be wholly due to the difference of altitude—for proximity to the sea counts for something in the amelioration of climate—but it is largely due to it. The influence of altitude may be seen in comparing the weather and other characteristics of a valley with the adjacent hills; the mere height means a lower average temperature, more rain probably, and more exposure to storm. Even the natural fertility and nature of the soil depend much on this, for the rains and floods are continually washing the richest soil material downwards to the valley or low lands, leaving the hills and higher ground impoverished, as shown in Figure 1.

We are accustomed to regard the climate of the hills as healthy and bracing, and so it is, as it is away from any of the miasma which often develops on low grounds or in the valleys. Over and over again it has been proved that the air of the mountains contains far fewer of the floating noxious microbes than is common in the valleys—as shown by the Swiss in bottling milk in the high Alps in a way that is impossible in the valleys. On the other hand, hill-bred folk are usually healthy and hardy because in the course of ages the more rigorous conditions of life have killed off the weaklings, and only the naturally hardy have survived to form the native population.

It is found that the fall of temperature is about 1° Fah. for every 300 feet of ascent, and therefore, apart from any local influence, the average temperature will be lower in the hill country than in the low lying country, or on the seashore, as the result of mere difference in height. This has a corresponding influence on the crops and live-stock, and means that we must have hardier

breeds or races of stock and crops for the hills than would be necessary on the plains and in the valleys, and a corresponding variation in the value of the land.

Besides the lower temperature, altitude generally carries with it some other drawbacks : there is usually a scantier soil, steeper land, less nutritive and satisfactory herbage, and a greater rainfall on the higher grounds, all of which reduce the value of the soil for farming purposes. For instance, wheat will not ripen over, say, 600 feet above sea-level, and even other cultivated crops cannot be depended on over 800 feet in Scotland and 1,000 feet in England. Most of our ordinary farming land is a long way below these heights, of course, but the point has to be studied whenever one approaches the hill country to look after land, and judged accordingly.

It may also be pointed out that the lower ground, being on the newer and richer formations, has generally the better soils—marls, clays, and sands—apart from the question of rainwash or surface drift, for even in a hilly country the level meadows in the valleys, glens, or straths are formed of better soil than the neighbouring hillsides.

Situation in a valley, however, renders a farm more liable to spring and autumn frosts. This is due to the fact that on a calm night the cold air descends, and thus the hillsides under such circumstances may keep a higher temperature while the valley drops to freezing point. On a slope on the Downs two stations about a mile apart were tested in February and March. The one station was about 100 feet lower than the other, yet it showed about 1° Fah. lower temperature than the higher station. This was due to the downward current of cold air, and the same results may obtain anywhere else under similar conditions.

III.—Climate

Apart from the individual characteristics of any given farm, the general climate of the district in which it is situated has much influence on its ability to yield crops and carry stock. The great factors affecting the farming are, as we have just seen, distance from the equator and height above sea level. Even within the comparatively small limits of the British Islands there are great variations due to these causes, with corresponding influence on the farming. As an example, it is a matter of common knowledge that a farm on the sea-level in the south of England will enjoy a more

genial climate than one, say, on the Grampians, a state of matters wholly due to latitude and altitude irrespective of a dozen other influences at work which may affect a given farm. Thus, the west coast of Ireland and the Western Hebrides may, and generally do, enjoy a milder winter than the south-east of England because of the incidence of the Gulf Stream, while the insular position generally helps to equalise matters. Still, these differences exist, and must be taken notice of and allowed for by farmers who propose to hire a farm in a district new to them.

One who has been brought up and accustomed to working land in a given district has been habituated to its climate, and instinctively and unthinkingly allows for it; but when he has to remove into a new neighbourhood he would be wise to find out what he is likely to have in the matter of weather, winter snows, etc., etc. When the change is made from north to south, or from the hills to the low lands, there are likely to be beneficial results, but if the change is the reverse way inquiry should be made on these points.

IV.—Rainfall and Water Supply

The rainfall statistics of the British Islands are pretty well known now, and every physical atlas contains a map showing the varying intensity of rain all over the country. The average rainfall of the west coast is 36 inches per annum, and of the eastern side 26 inches, but the local fall of any particular spot may be above or below these figures.

For instance, parts of Essex and Lincoln only show from 18 to 21 inches per annum on an average, while such places as Glen Croe, in Argyllshire, and Sty, in Cumberland, run up to over 200 inches.

On the other hand, districts that are usually "dry" in the ordinary run of years may have a "wet" year, as happened a few years ago in Essex and the south-east of England generally, when the usual fall of, say, 20 inches, ran up to 36, with correspondingly disastrous effects on the crops and soil. Such a state of affairs is only a temporary accident, however, and the average rainfall is what a farmer should know.

The kind of farming followed depends to a large extent on the rainfall. The east side of the country has always been noted for corn and arable farming, and the west for grass and dairy work, solely because of the difference in the rainfall. In a wet district tillage and the proper preparation of the soil for crops is at a

discount, while a lot of corn could not be handled in a locality where rain in harvest time is the normal state of matters.

Per contra, dairying is carried on at extra expense in the eastern counties, where the grass is liable to disappear in a hot dry summer and autumn, and lush food becomes scarce and has to be supplemented by "artificial" food-cakes or meals.

Rainfall of course does not wholly depend on the position of a district with reference to its position east or west, for there are many modifying factors influencing local rainfall : such as situation with regard to hills, forests, plains, rivers, lakes, seas, etc., but the general facts are that our rain clouds in these islands come from the Atlantic with the west and south-west winds, and that therefore the western and south-western parts of the kingdom get the first and biggest share of rainfall, and the eastern and north-eastern get least. The deviations from this rule are due to local influences which are generally apparent, and which of course the natives of a given district are used to, but a new-comer must take note of and adopt his system of farming to such deviations.

Examples may best illustrate the influence of rainfall on the system of farming. A Scottish farmer on coming to the south of England attempted to grow swedes and turnips in the same way as he was accustomed to in the north : result, failure, because the rainfall was not sufficient to swell the roots and prevent mildew where mangolds would have succeeded. Again, a farmer coming from the west of England to Essex failed to grow mangolds till he learned the practice of growing them "on the flat" combined with heavy rolling so as to stimulate the capillary action of the soil and thus counteract the drought : in the west he was accustomed to "ridging up" the roots so as to carry them above the excess of water supply.

The rainfall is chiefly dependent on two things in our country : height above sea level and proximity to the west. The geological structure is such that the older and harder rocks have the highest hills and are mostly situated to the west, as in Wales and Scotland and thus the wettest and highest districts and the oldest rocks coincide. As a rule, all places over 800 to 1,000 feet high have a rainfall of 100 inches per annum and over, while the low-lying eastern counties have the lowest amount.

Thus, if a line is drawn from Snowdon to Essex it will cross all the geological formations from the oldest to the youngest ; it will be *downhill* all the way, and it will range from the wettest to the driest parts of the country, as shown in the following table, which also

indicates how the prevailing farming is influenced by these rainfall conditions :—

	Primary Rocks.			Secondary Rocks.					Ter- tiary Rocks.
	Merioneth	Montgomery	Salop	Worcester	Warwick	Northants	Beds	Herts	Essex
Rainfall: approximate inches per annum	100	95	45	35	30	27	25	22	20
Height above sea level : approximate feet	900	700	400	300	270	250	230	220	200
Percentage acreage under corn	11.1	20.3	22.4	26.2	25.7	29.8	42.0	42.3	46.3
Percentage acreage under grass	75.9	63.8	58.2	52.9	56.4	52.8	31.4	29.7	24.2

Water supply.—Intimately connected with the rainfall of a district is the water supply of the fields and farms. A "well-watered farm" is one that is "desirable" in one respect at least, for the household and live stock must be supplied somehow with drink during the hot months of summer, and a fair supply of wells, ponds, ditches, and watercourses is of the first importance.

We can always find plenty of water by boring far enough downwards, but the conditions of an ordinary farm seldom justify the outlay necessary to go down, say, several hundreds of feet and fix the necessary pumping machinery. Even where the "water table," or surface of the saturated body of the underground layers, is within thirty feet of the surface, and can be tapped by a common hand-pump, the labour necessary to supply a lot of stock will be very considerable, though nowadays we can adopt a windmill pump.

We have in any case, therefore, to depend more or less on ordinary surface or spring water derived directly from the rain supply. The supply for the homestead may be brought in pipes from a distance or pumped from a well, but the supply for the stock out in the fields is quite another matter.

Access to a river or a stream which never runs dry may be worth many pounds to a farmer in a year, while a sufficiency of ditches or ponds about the fields is absolutely necessary. The amount of rain that falls on every farm is quite sufficient to supply it if the water could be saved, but usually it runs off into the streams and is lost.

unless it happens to go to supply a spring yielding a steady flow.

Of course, much can be and should be done to save rainwater. A pond may be dug at a convenient corner so as to supply several fields, or a dam may be made across a hollow, but these cost money to make, and the outlay is a set-off against the value of the farm, so that what may be called a "natural" supply of water about the fields is of great value to a farmer.

It is of course understood that the water is of good quality. If there is any taint of sewage the taint must be stopped or the water discarded, and this is a point specially to be seen to in the case of wells situated in or near the farmstead. In certain mining and manufacturing districts, again, the supply may be polluted by foul water directly discharged into the watercourses.

There is a very great difference between the various geological strata in their power of holding water and yielding it for farm purposes. As a rule the clay formations are "dry," that is, there is no volume of underground water in them that can be tapped; on such beds as the London Clay, the Gault Clay, Kimmeridge Clay, Oxford Clay, Upper and Lower Lias Clay, and Keuper Marl, ponds or dams require to be made to catch the surface water, unless it can be brought in pipes from an adjoining deposit.

All the limestone beds—Chalk, Oolite, Lias, and Carboniferous—are full of water, but it is always hard and may be at a great depth.

All the sands and gravels are also full of water, more or less soft, and as these are generally near the surface they are very often the most convenient sources of well or spring water on a farm where surface pollution is not allowed to take place.

The older rocks, composed of grits and shales, also hold much water in their fissures, and it is of soft quality.

There are very few farms on which water cannot be found somewhere within their bounds, at a reasonable depth from the surface, though it may have to be pumped up. If it can be found *above* the homestead, then a gravitation supply may be arranged; even the making of a large pond by digging or damming up to catch the surface water may pay, and will be quite satisfactory if pollution is prevented.

V.—Shelter

All our domestic animals and plants, having been developed by human care, always grow better and give better returns when sheltered and kept under comfortable circumstances. A thoroughly

equipped farmstead is necessary to house all the live stock, crops, etc. and if it does not already exist it should be made.

Again, the homestead itself should be in a sheltered nook if possible, not too low down, and not too far away from the centre of the land, and in a position to get the sun as much as possible.

Lastly, the sheltering of the whole farm from storms is a matter to be attended to. In this country our cold and stormy weather mostly comes from the north, north-east, and east, and consequently a range of hills or high ground in these positions will improve the general climate of a farm very much, and make it more valuable for farming purposes, while exposure will reduce its value.

On the other hand, the sheltering may be improved artificially by planting woods or strips of plantation along the exposed sides, while all "broken" land — *i.e.*, rocky ground, steep sides near brooks and rivers, and places which cannot be cultivated, or cut for hay if in grass, should also be planted. This, however, is the landowner's work, and a tenant has to take things as they are, but he will be wise to note such matters.

Too much timber is, of course, a drawback, because it is apt to lodge excess of game, and therefore the happy mean must be aimed at.

Even a big hedge is not to be despised. It is, no doubt, unsightly on a farm to leave the fences untrimmed, but they certainly act as windbreaks, and immensely improve the comfort of the live stock. A good healthy hedge, too, is a very good indication of the cropping power of the land.

A stranger visiting a district for the first time can generally get a good idea of the effects of the want of shelter by noticing the trees: if a given farm or the whole neighbourhood is exposed the trees will grow lopsided, and hang away from the blast. Even the thatch on the stacks will give a hint; if roped down with string or yarn it means there must be a lot of storm and wind, while if left bare it will indicate a reasonable amount only of wind or exposure.

VI.—Aspect

Does a farm "lie to the sun" or does it not? is a question always asked by farmers in discussing the capabilities of any farm. A farm on a plain, like the prairies of the West, or on the bottom of a wide valley, like the "carse" or estuaries of some of the rivers in the British Islands, cannot be said to have one kind of aspect more than another, but in the greater part of these islands the land is at least

undulating if not actually hilly or mountainous. The consequence of this is that the fields have more or less of a slope, and if the slope looks southward towards the sun it is worth more for farming purposes than if it sloped to the north.

This is due to the fact that the sun's rays strike the land with a southern aspect more directly than when the slope is the other way, for, indeed, the northern aspect of a range of high hills may never see the sun at all—at least in winter time. (*See Fig. 7.*) This state of

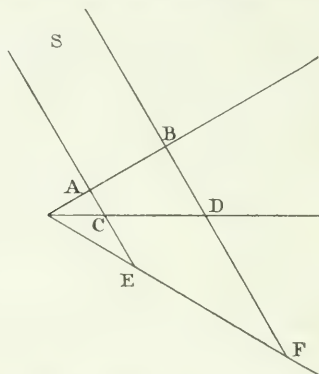


FIG. 7.—ASPECT. LET S REPRESENT A RAY OF SUNSHINE: ON SLOPE A B IT IS CONCENTRATED ON TO THE SMALLEST SPACE, ON LEVEL C D IT IS MORE WIDELY DISTRIBUTED, WHILE AT E F IT IS FURTHER WEAKENED BY DISSIPATION OVER TWICE THE AMOUNT OF SURFACE THERE IS AT A B.

matters has a vast influence on the farming value of the land and the working details of it.

In a valley known to the writer the crops on the north side are always a week ahead of those on the south side (with a northern aspect), and as early potatoes are largely grown this means many pounds more per annum received for the produce grown on the north side where the slope faces the sun.

In the case of the natural cover—pasture—there is more liability to “fogging up,” that is, to get overgrown with various mosses, on the northern exposure than on the southern.

When the slope is at an angle of 25° to 30° it receives the sun's rays at the nearest approach to a right angle in our latitudes, and consequently every acre receives the maximum possible amount of sunshine, but a slope of this steepness is uncomfortable to work

on or cultivate, and may have to be ploughed with a "one-way" plough across the face of the slope, if ploughed at all.

The difference between the various aspects may be seen any winter by noting the falling of the snow and its melting when the thaw comes: the slopes facing the north round to east get the most snow, and get it oftenest, while the other sides of the hills or the valley get little, and it melts more quickly.

All this has a very great influence on the treatment of stock and the cultivation and other work of the farm, and the practical farmer takes note of these things in assessing the farming capabilities of a district or a particular farm.

On the plains in various parts of England—the newer formations these differences do not exist, for where the ground is not actually even or level it may be only slightly undulating, and the differences be infinitesimal, but in many cases even there the difference between a very small slope *to* and one away *from* the sun is quite perceptible in its effects on the soil and the crops.

The difference in temperature from aspect alone is very considerable. The soil on the slope to the north may receive one-third less sunshine than one to the south, and be 7° to 10° Fah. cooler in temperature. Even a gentle slope to the south may be from 3° to 5° Fah. warmer than the same soil on the level.

Yet another point arises which depends on the aspect of the fields. In this country the prevailing winds come from the south-west, as does by far the greatest amount of the rain. The result is that the slope which faces that direction and gets the greatest share of sunshine also gets the greatest force of the rainfall. Now, as before explained, the rain-wash on a slope has much to do with the texture of the soil, and so on the south-western slope we expect to find much of the finer earth washed out and the soil more sandy or granular than the same kind of soil with a different aspect. Actual investigation has shown this to be the case, and perhaps this fact explains why some of the finer grasses are found on the north-eastern sides of a hill, and why the sheep prefer to graze there in spite of the tendency to fogginess. There is no end to the complications introduced into farming by the freaks of our salubrious climate.

VII.—Contour

The two extreme examples of the differences of contour to be met with on farms are the levels of a marsh, plain or meadow and the

ruggedness of a precipitous mountain. We meet with both extremes within our islands and with countless combinations of variations between them.

At the first glance it will be realised that the horse and manual labour on a farm will be very largely affected by the levelness or steepness of the land, and that labour will be most conveniently carried out on the level ground, but be next to impossible, or quite impossible, in a rocky, hill country. Apart altogether, therefore, from the nature of the soil, its fertility, altitude, aspect, and a score of other factors influencing the farming, the mere nature of the surface of the farm as regards its ups and downs will have a tremendous influence in determining the kind of farming to be followed.

In a hilly and rocky region, sheep- and cattle-farming only can be followed, and cultivation will be limited to the few alluvial spots alongside the streams in the valleys ; in a wide level or undulating country every acre can be under the plough if so desired, and the live-stock farming is determined very largely by the cultivation.

While level land is very convenient and suitable for arable work, it must, of course, be pointed out that dead levelness (if absolute levelness of land could exist) is not desired because of drainage considerations. The ground in its natural state absorbs less than a half of the rainfall, and the rest has to run off the surface somehow into the nearest ditch and brook, and then to the sea. All land has therefore been deposited—or subsequently weathered and washed—with some slope naturally, and where this is not so a marsh or a lake is formed.

In modern farming, however, the natural drainage off the surface is not enough, but has to be aided and developed by subsoil “thorough” drainage with pipe-tiles laid in trenches at regular intervals all over the land and covered in. These pipes must have a “fall” of not less than eight feet to the mile, but as much more as possible without going to extremes, and therefore the contour of the land most desired is one with sufficient undulations or slope to keep it free of surface water and to carry the superfluous underground moisture off easily.

The contours of a district depend almost entirely on the nature of the underlying geological formations, and as the nature of the soils depends on these as well, it is no wonder that Arthur Young, in his historical journeys and inquiries into the farming of England, at a time geological study was undreamt of, came to the conclusion that the contours wholly determined the nature of the soils.

On the older formations the contours will be steep and precipitous : on the newer ones more moderate, while on the recent formations we find the most of the low-lying, undulating or level districts of the valleys, fens, meadows, corses, etc.

The contour features of a district depend so much on the nature of the geological formations below that it is quite possible for anyone who has studied scenery to tell what these formations are, merely from their appearance in the distance, for each kind of rock has its own contours and "scenic" effect.

The contours of a farm or district influence greatly the exposure, shelter, aspect, etc. On a plain approximately level there is no natural shelter, and artificial shelter with trees and buildings has to be made : in a hilly district there is abundance of sheltered hollows which add greatly to the value and amenities of a farm and counter-balance the drawback of steepness : but a kind of medium is more to be desired.

VIII.—Sea Influence

One of the great factors which control our climate as a whole is the sea which surrounds these islands. The general temperature of the coast-line all round is higher than farther inland, and it is also kept more equable. Farms on the shore are, as a rule, "very desirable" for these and other reasons, if there are no drawbacks such as a rocky country, a great rainfall or anything else that counteracts the value of the sea breezes. In considering the particulars as to sea influence, we find that the Gulf Stream is of the first moment.

Gulf Stream. The great factor in equalising and improving our climate is the Gulf Stream, that huge body of warm water that flows across the Atlantic and washes our shores. If it were not for this, our winters would be as bad as those of Labrador. It is the influence of this that makes the climate of the west of Ireland, the Scillies, etc., so mild—if wet—and conduces so much to the production of early crops in these districts.

An example of its influence is given by the growth of early potatoes in the south of Ayrshire : this district is just opposite the opening between Ireland and Cantire, and is free from spring frosts, and so here for over a generation early potatoes have been grown. In the same way the Channel Islands and the Scillies have long been celebrated for early flowers and vegetables, and the west of Ireland will also be at some future day, when the natives wake up to the potentialities of their country.

Wherever the shores of these islands face the west that district has its climate profoundly modified for the better in the matter of temperature, and has its winter and spring growth of crops immensely helped.

The influence of the sea is seen in our islands in another way : the average winter temperature all round our coasts is the same at sea-level, 37° Fah. for the east and 39° Fah. for the west. The influence of latitude is felt in summer in making the south country warmer than the north, but the tempering influence of the sea shows in the cold weather. This influence does not go very far inland, or very high above sea-level, and is therefore one point very largely in favour of a shore farm.

IX.—Natural Vegetation

As the soil has been largely made or modified by the growth of the plants on it, so, in like manner, the plants have been modified by the action of the soil on them, and each type of soil has developed a natural flora to suit itself, which would not thrive so well if transplanted to another kind of soil—assuming that other circumstances were the same. We see this very distinctly exemplified in the case of timber trees : oak thrives on clay, elm on loam, beech on limestone and marl, birch and pine on poor sand and gravel, and so on, and it is almost possible to tell the nature of a soil from a distance by noting the prevailing kind of timber tree.

Coming down to the smaller plants, we find such examples as the sand grass (*Ammophila arundinacea*) on the sandy seashore ; Yorkshire fog (*Uolcus lanatus*) on peat ; rest-harrow (*Ononis arcensis*) on clay ; horsetails (*Equisetum arcensis*) on wet sand ; spurrey (*Spergula arcensis*) on sandy loams ; red poppies (*Papaver Rhœas*) on gravelly soils, and so on, with a score of similar cases, characterising the different soils.

Some plants, for instance, such as lupines, serradilla, gorse, and heather, are intolerant of lime in the soil. Other plants, again, such as the beech, yew, and box, like a limy soil, while among crops, clover, beans, and peas like a fair amount in the soil ; the “boiling” quality of peas, indeed, being considered to be due to the lime.

It is, indeed, quite possible to draw up a list of the plants which are peculiar to, or thrive best upon, the different classes of soil—from trees downwards—while some individuals are confined to the soils of certain specific geological formations. The most common and extensive cases may here be given by way of example ; such

cases as take the attention of anyone passing through a district or making a cursory examination of the outstanding features of a farm :—

SANDY SOIL

Conifers	Lupine
Birch	Birdsfoot Trefoil
Rowan	Serradilla
Spanish Chestnut	Couch Grass
Hazel	Spurrey
Holly	Poppy
Gorse	Marigold
Broom	Sandwort
Bracken	

LOAMY SOIL

Elm	Coltsfoot
Ash	Charlock
Sycamore	Wild Radish
Chestnut	Bindweed
Apple	Yellow Rattle
Pear	Couch Grass
Yarrow	Groundsel
Ragwort	Chickweed

CLAYEY SOIL

Oak	Primrose
Hornbeam	Trefoil
Poplar	Wild Oat
Restharrow	Field Foxtail
Knotgrass	Marsh Bent-grass
Buttercup	Mayweed
Wild Carrot	

MARLY AND CALCAREOUS SOIL

Beech	Gorse
Larch	Sainfoin
Wild Cherry	Lucerne
Yew	Kidney Vetch
Juniper	White Clover
Box	Wild Parsnip

PEATY SOIL

Birch	Barren Brome-grass
Heaths	Yorkshire Fog
Cotton Grass	Quaking Grass
Soft Brome-grass	

The above lists are not intended to convey the impression that the plants named are confined to the respective soils ; they are only intended to indicate the preferences that the plants seem to have, and that where found growing naturally they “predominate” on some soils and are scarce or absent on others.

So striking is the suitability of some trees to certain formations that the late Prof. Buckman compiled the following table to illustrate the fact. The figures represent comparative values, and thus indicate the failure or unsuitableness of our standard timber and fruit trees, as well as their successful growth, under different soil conditions :—

<i>Rocks.</i>	<i>Oak.</i>	<i>Elm.</i>	<i>Beech.</i>	<i>Pine.</i>	<i>Apple.</i>	<i>Pear.</i>
Chalk	2	4	8	5	2	0
Greensand	3	7	0	3	3	1
Gault	6	6	0	0	4	1
Oxford Clay	10	8	0	1	6	0
Oolite Limestone	1	4	10	5	2	0
Lias	5	10	0	1	10	3
New Red Marl	7	12	0	2	8	0
Mountain Limestone	2	2	3	1	1	0
Old Red Marl	8	10	0	1	15	8

While the native plants of the soil thus have various predilections, and predominate in some districts and disappear in others, the cultivated crops of the farm have similar tendencies. Thus clay land suits wheat, oats, and beans best, and the best qualities of these are grown on the heavier soil. Barley likes a loamy or intermediate soil, while rye is the “corn” of light sandy districts.

Among “root” crops, mangolds thrive best on the stiffer soils, while a “turnip soil” is pre-eminently one of a loamy, friable nature, and carrots thrive best on the lighter sandy variety. Potatoes in particular are influenced by the soil. Thus the red loamy soil of Dunbar is notable for growing the “Dunbar Reds,” the finest kind of potato in the market, while the Fens produce the “Blacklands,” which are not worth nearly so much per ton.

Thus there are differences in the crops from the influence of the soils altogether independent of the cultivation and manuring. Many of these differences are of world-wide significance, while many are only known locally, but they have an important bearing on the systems of farming and are fully recognised by practical farmers.

A soil may be very much "improved" by draining, liming, manuring, etc., but its original characteristics and possibilities remain the same to a very great extent and cannot readily be altered.

These differences in the natural vegetation may be said to be due to the texture and chemical composition of the soil alone, but, of course, the "climate" of a particular spot, its exposure, altitude, etc., have a great influence on the character of the vegetation as well.

* * * * *

There are so many of these physiographical factors working at cross purposes, as it were, that it is sometimes rather difficult to unravel the subject and assess the value of each in influencing the cropping and stock-carrying capacity of a farm. Nevertheless, it is necessary to make some attempt at judgment in this line, where a would-be farmer is proposing to rent a given farm. A man who is already settled in a farm will equally find it to his benefit to take notice of these conditions and circumstances and farm accordingly.

CHAPTER IV.—THE IMPROVEMENT OF THE SOIL

THERE are several important operations or methods which can be carried out for the purpose of permanently improving soils. A piece of land—even a rich prairie—in a state of nature is not just ready for farming until many things have been done to or on it. It may be excessively wet, or excessively dry ; it may be deficient in lime ; it may be stony or bouldery ; while, of course, it needs “equipment” with buildings, fences, roads, etc. Apart from these latter, there are various methods of improving the soil, as distinct from “equipping” the farm, and these we may now proceed to discuss under divisions : (1) Draining, (2) Stone Clearing, (3) Liming, (4) Irrigation, and (5) Manuring.

I.—Draining

One of the first things that requires to be done to improve land in this country, in nine cases out of ten, is to drain it properly. The actual method of carrying out the engineering work of draining a field will be treated in its proper place, and only the facts pertaining to the effect of drainage on the soil can be explained at this stage.

There is a heavy rainfall in the United Kingdom generally : even in the Eastern Counties it reaches 20 inches per annum, while in Cumberland 225 inches are reported in some spots. Of this rainfall part soaks into the ground, part runs off into the ditches and streams, and part is directly evaporated. That which soaks down into the ground gradually accumulates in the lower layers, until it rises high enough to run off at some outlet in the shape of a spring, or oozes out on the sloping side of an incline to make a piece of wet, swampy land. Where this subterranean body of water rises to within less than thirty feet of the surface it is possible to get at it by a well, and to raise it by a common pump. The surface of the water in the well shows how far up complete water-loggedness exists, but between that “water-table,” as it is called, and the surface of the ground there are varying proportions

of moisture present. Thus on the surface in dry weather there may be almost absolute dryness: a foot or two down, 20 per cent. of water present; another foot or two farther down, 40 per cent. present, increasing in ratio until the actual body is reached with 100 per cent. of saturation water. (See Fig. 5.)

Now, all plants require moisture, but on stiff retentive soils, or on the heavier soils in continuous wet weather, there may be too much water held by capillary action or by temporary saturation, ending in the "souring" of the land, the chilling of the roots of the plants, the prevention of the access of the air with its oxygen, and the eventual killing, or at least stunting, of the cultivated plants on the soil.

By putting rows of pipe-tiles at regular intervals up and down the fields at a depth of two to three feet the surplus water is removed, the interstices in the soil opened to the passage of the air and the roots of the crops, and the temperature of the soil raised.

The beneficial effects of draining are so many and varied that it is desirable to take them up and explain them categorically as follows:—

1. *Texture improved.*—The mere removal of the excess of water results in a certain amount of curdling or granulation of the clay in a stiff soil. No doubt this is partly due to the oxidising action of the air which follows the removal of the water, and to the salts in solution in the soil water—such as bicarbonate of lime—as the removal of the excess immediately causes its circulation, either downwards by percolation or upwards by capillarity. The practical result of this is that the soil becomes more friable and more easily worked by the implements of husbandry, apart from any other treatment. This improvement goes on very slowly, of course, but when once the clayey material has shrunk into blocks by actual fissures, or has merely had the formation of curdled grains, it is never so sticky or unworkable again.

2. *Roots go deeper.*—When the stagnant water is gone the roots have a chance to penetrate deeper. If the under layers are full of sour and poisonous water roots can only grow downwards for a limited space in the top soil, but if the excess of water is removed and the soil is sweetened then they can descend into the deeper layers, and thus have a wider range of feeding ground. It is in this way that draining prevents the evil effects of a drought. The roots go so much deeper that the crop is independent of surface conditions and gets enough capillary water to keep it going.

3. *Temperature raised.*—The removal of the excess of water

reduces the amount to be evaporated, and thus the sun's heat warms the soil without wastage, while the air and rain will get a chance of carrying the surface temperature downwards. Water is a poor conductor of heat, and therefore the warmth of the sun's rays is carried very slowly into the soil when it is wet: if drained the ordinary action of conduction will warm up the particles of soil much more quickly. There may be a difference of from 5° to 10° Fah. in temperature between a drained and undrained soil simply from the presence or absence of excess of water.

4. *Water allowed to get in.*—It has been said that draining is carried out not so much to get the water out of the soil as to get it in. The rain that falls always brings down a little fertilizing matter (such as ammonia) with it, while any manure on the surface supplies more. If the soil is already full of water this fresh lot cannot soak downwards with its load of fertility, and thus is apt to be lost in the nearest ditch. When, therefore, the pores of the soil are open the fresh showers have a chance to percolate downwards, and carry with them all the extra fertility in solution into the body of the soil.

Paradoxical as it may seem, draining makes the soil more moist. It substitutes the film of capillary water—in which only the roots of plants can feed—for the sodden state, while this film water is most plentiful in the warm growing season, and there is a greater cubical space in which it can form and serve the roots. The total outcome of this is that a soil is drier in a wet time and moister in a dry season than before draining.

5. *Rain-washing prevented.*—If the rainwater cannot immediately percolate downwards it collects on the surface, and when in sufficient quantity it runs off down the furrows and hollows to the nearest ditch. If the quantity is excessive it will carry with it a lot of the finer soil, but even where this does not happen it will yet carry off in solution all the elements of fertility from the surface. This is, perhaps, most noticeable after a thaw where dung has been carted out and spread on the surface while it was yet frozen. When the thaw comes the soil below is hard so that the surface water cannot get down, and therefore runs off into the nearest ditch carrying with it the brown essence of the manure. This is exactly what happens with water-logged land, though perhaps in a lesser degree, and the removal of water by drain-pipes below is the first necessity to cure the evil, while if followed by subsoiling or trenching so much the better.

6. *Lime and manures act better.*—Draining is imperative before we can get any good from a dressing of any sort. Apart from the

probability of the manurial compounds being actually washed off the surface, there is the certainty that a wet soil will not be benefited very much, even when the manure or lime is actually in the soil. The useful microbes cannot work in stagnant water, the oxygen of the air is not brought into contact with the components, and thus the benefits are lost.

7. *Crops grow better.*—As a result of the improved texture of the soil, the better capillarity, oxidation, and action of manures, etc., crops of all kinds grow better. This, of course, is the principal ultimate result that is desired, and to which all the other things are expected to tend. On a natural pasture the coarse “bents,” rushes, and other inferior growths disappear after draining, and the good grasses show up and thrive, to be followed in many cases by white clover if there is a little lime in the soil. Among arable crops the finer varieties can be grown after draining, while there will be a stronger and healthier plants of all kinds.

8. *Green crops can be introduced.*—On undrained soils of the stiffer class root growing cannot be followed, and the land has to be cleaned of weeds by an occasional bare-fallow. The draining of stiff soils can be immediately followed by fallow crops, such as mangolds, swedes, etc., and green-cropping carried out systematically on all but the heaviest soils. Bare-fallowing is not likely to be abandoned, for several reasons that will be discussed in due course, but draining makes it more possible to substitute a root crop by making the soil drier and more friable.

9. *The general climate is improved.*—A rise in the temperature of the soil, a reduction in the amount of moisture evaporated into the air, a better utilisation of the sun's heat, and a drier soil under foot, all tend to improve the local climate. The damp raw feeling in the air at night or in wintertime is partly done away with because the average temperature of the air is raised, the ground is much more comfortable to walk over or work upon, while the live stock which graze over it and lie upon it have their general health very much improved.

When the water in the soil is constantly dissolving out small quantities of the manurial components and carrying them downwards, it is apparent that the removal of the water through an underground drain will also mean the carrying away of fertility, and this is what really does happen.

For many years the drainage water of the manurial plots at Rothamsted has been tested, and it has been found that certain proportions of bicarbonates, sulphates, chlorides, and nitrates were washed out. The chief basic body combined with these was lime, but

there were also small quantities of soda, magnesia, potash, and ammonia. Phosphates escaped in very small quantities. It is the nitric acid of course that is of most importance among the acids, and the lime among the bases, and the loss of these must perforce be set down as a drawback to the benefits of draining.

This loss is of course greatest in heavily manured fields, and it is also greatest in open soils of little retentive power. It can be minimised by putting manure on in smaller dressings at more frequent intervals, and using bulky organic manures, like dung or compost, on porous soils as much as possible ; while the immediate planting of one crop (especially a leguminous crop) after the first one is off helps greatly to "fix" the fertility.

The actual loss in pounds per acre per annum, where ten inches of rainfall is computed to have escaped by the drains, has been ascertained on various plots at Rothamsted as follows :—

Lime	98 to 226 lbs. per acre
Magnesia	5 to 20 lbs. per acre
Potash	3 to 12 lbs. per acre.

Of the acids the only one of any importance is nitric acid, and it is lost at the rate of anything from 8 to 220 lbs. per acre per annum. These figures vary very much and depend on the nature of the soil, the kind of crop grown, and the manures applied, but the point is that there *is* a loss in this way.

As draining has been systematically practised all over the country for more than half a century, most of the farms are now drained, but occasionally we come across a field not done, or which needs some extra drains to be put in. As already explained, drains will often do good even where no water ever runs into the pipes, so that in nine cases out of ten land should be drained if not already done.

The signs of wetness in land are generally pretty evident. On pasture there will be a tendency for rushes, sedges, and coarse "benty" grass to grow, while the ground may be actually swampy in parts. On arable land the excess of water will be more apparent ; the water will sit in the furrows, the furrow slice will be pasty and glistening as it is turned over, and, of course, the surface will be always wet, for even in the drying winds of spring wet patches will show up.

Level lands, such as riverside meadows and estuarine deposits, are more liable to be wet and in greater need of draining than hill-sides or undulating land. The reason, of course, is that the slope in

the latter case conduces to the water running away either on the surface or by slow percolation beneath, while on level land it is bound to lodge there for want of a natural outlet.

For this very reason land that has been ploughed in high narrow ridges or stetches before draining may be laid down in "flats" afterwards with ordinary open furrows every fifty feet or so. On wet land, laying it up in narrow stetches of seven feet wide with a furrow between each was the custom, so as to promote surface drainage, but the thorough underdrainage of a field renders this unnecessary, and the soil may be levelled down. The ancient ridge-and-furrow system still holds in many districts, however, though the need for it has gone.

II.—Stone Clearing

To some people it may be a surprise to hear that in many districts one of the most necessary of improvements is to clear the land of loose stones, when either on the surface or embedded in the soil near the top. On the newer and clay formations of the south and east of England the want of stones is one of the drawbacks to farming, but on many of the older and more indurated rocks, stones and boulders are in many cases an absolute nuisance. This is especially the case in the glaciated area of the country, where actual boulders may be common.

On the rougher ground on the hills, where pasturage is the only possible kind of farming, it is not generally necessary to do anything with the stones and boulders, but wherever the land is required for arable purposes it must first be cleared of this "rock-wreckage" before the ordinary implements can be got to work comfortably.

In the olden days, before the manufacture of drain-pipes was properly developed, a system of drainage with stones was in vogue in stony districts: the trenches were dug up and down the fields in the ordinary way, but instead of laying pipe-tiles in the bottom these were filled a foot deep or so with the stones off the land. In this way two important methods of improving the soil were carried out at one operation.

As soon, however, as the plough and the cultivator dip into the soil, a fresh crop of stones is brought up, which must be removed in turn, and so the process goes on almost interminably.

In stony districts a favourite way of getting rid of stones was to build them into the dykes or stone fences. A sleigh was the most

convenient carrier for short distances, while for big boulders it was the most easy vehicle on which to place them.

The work in some cases has been carried on by two generations of farmers, and is not completed yet, for often a fresh lot of stones works up to the surface from below. The frost penetrates down about two feet or so, and heaves up the whole of the soil and subsoil : when the thaw comes it drops back again, but the soil drops more than the stones, and so these gradually work upwards to the top.

The expense that has been incurred in some cases is enormous, and quite equals, or amounts to more than, the cost of thorough drainage per acre. It is, of course, a job that has been done little by little, year by year, and therefore sometimes the farmer and his men have not realised the total cost or the amount of labour entailed. If a field was "broken in" for the first time on a rough hillside, the loose surface stones were first gathered up and carted or sleighed off out of the way somewhere. Then the first ploughing turned up another lot of stones or rock fragments to be again gathered off. This process has probably been repeated year after year every time the field has been worked, until indeed the country people begin to think that the land "breeds stones."

Of all the geological formations the Boulder Clay is the worst for stony deposits, for it is full of the wreckage left by the Great Ice Age, and in many districts cultivation is impossible because there is such a vast amount of it present that the field could not be made workable, though the soil itself may be all right.

It is an "improvement" for the farmer to clear the land in this way, and it is one that deserves repayment of the "unexhausted value" to a tenant on quitting his farm, but though a great and a necessary improvement it has seldom been recognised in this way.

The above operation must not be confounded with the "stone picking" of the southern counties, where flints are plentiful on the land. In such districts road metal and similar material are very scarce, and it is only the flints picked off the land that can be found for this purpose, together, perhaps, with flint gravel found in beds or layers in various spots. The picking is generally paid for at the rate of one penny per bushel, and is not an "improvement" to the land, excepting where the flints are very large. There have been cases, indeed, where removal of these stones has injured the soil by making it colder and later, and they have had to be spread back over the field again.

Of course, the kind of stones that need removal vary according to the nature of the subjacent rock ; in some cases the stones may be

fragments of limestone, as on the "brashy" soils of the Midlands, or boulders of granite on the northern hills, but their removal is necessary for arable work, and is one of the first operations required in "making" a farm.

III.—Liming

There are very few soils that do not require a dressing of lime for the purpose of ameliorating their physical condition and of developing their fertility.

Lime exists in all soils to some extent, but it has a constant tendency to be washed out or downwards. Even on soils that lie immediately over the chalk or other limestone formation there may be a deficiency of it, although the solid rock may be only a few inches below. This is owing to the fact that water containing carbonic acid gas has a great solvent power.

In the decaying humus in a soil this gas is evolved, to be absorbed by the rainwater, and the compound in turn attacks any particles of limestone or marly matter present, and dissolves and carries it downwards in solution. In this way a soil is gradually depleted of the lime which may originally have been in it.

Now, apart from the action of lime as a manure—which will be treated of in its proper place—it is essential in all soils because of its value in other ways.

Of all the component parts of a soil the most important one is lime, for though it is not so necessary as a plant ingredient itself, yet it is the great controller of fertility in the soil. Wherever limestone predominates in a district we have a "rich" country—both the live stock and the crops are healthy and thriving, and a want of lime has a correspondingly disastrous effect.

It has been pointed out by some authorities that the secondary quality of the crops and stock on the older, rugged, hilly formations is principally due to the want of lime in the soils and the parent rocks, and that an artificial application of lime on them is followed with striking results.

Wherever the soil is found to contain less than one per cent. of lime in its constitution, then a dressing in some form or another is necessary.

When lime is dissolved out of a soil and washed downwards it is very often re-deposited at a lower depth as a "pan," by the loss of the extra carbonic acid. This must be broken up, of course, by subsoil work, if possible, and sometimes the turning up

of this calcareous deposit is as useful as an actual application of lime.

The effects of a dressing of lime on the soil are many and varied. On a sandy soil it has actually a cementing or stiffening effect, so that there is less of the leaching by passage of water than before, while the capillarity is increased, and the general character of the soil improved.

Another of the actions of lime is that on the clay in the soil. This for want of a better term may be described as a kind of coagulation or flocculation of the silicate of alumina or the colloid part that is present there, presumably by driving out the water of combination in the clay molecules; in practice it means that a clay soil that has had a dressing of lime is made more friable and crumbly, and less sticky when wet, and much more easily cultivated; the physical characteristics, in short, are improved.

As a result of this curdling, which appears to be physically the segregation of the molecules of clay into grains, the capillary power of the soil is reduced; less water will soak upwards from below, thus leaving the soil drier, while the percolating power downwards will be improved.

The curdling effect of lime on clay can be very well exemplified by shaking up some muddy water in a glass and allowing it to settle. The fine particles of clay float in the water and will not settle, but when some lime water is introduced this precipitates in a short time, leaving the water clear. The exceptional sparkling clearness of streams off the limestone formations is due to the lime in solution in the water keeping down any tendency to muddiness.

Again, a soil with sufficient humus or organic matter in its composition is liable to develop various organic acids (such as humic, geic, crenic, etc.) in the act of decomposition. These are poisonous to our cultivated farm plants, but a dressing of lime unites chemically with these and renders them innocuous, if not useful, and thus in the language of the farm "sweetens" the soil. Our crops will not thrive in an "acid" soil, but must have it "basic" or neutral, and lime is the best "base" to use.

In recent times we have found out that much of the fertility of a soil and its ability to yield crops depend on the presence and activity of various kinds of microbes. The principal kinds are those that produce nitric acid from their action on nitrogenous material. These, however, choke themselves, as it were, with the acid they secrete unless there is some basic body to take up their

secretion. Thus lime comes to the rescue, and liming is equivalent to improving the supply of nitrates in the soil.

Lime, again, unites with some of the double silicates of the minerals in the soil, and by replacing potash sets it free for food plants. There is no doubt that it causes many more reactions of a chemical nature, which all tend to render the "dormant," or insoluble, residues of the soil of "active" value to plants, by reactions which produce soluble compounds.

Another result of liming is the prevention or cure of "finger and toe" disease in turnips. This is due to infection by a "slime fungus" which can only thrive in an acid soil. The basic effect of lime cures this and reduces the attacks of the disease, while the setting free of some potash in the soil compounds—as noted before—is also considered beneficial in this respect.

In the olden days liming a field was a tremendous job, for five tons per acre of quicklime were commonly applied in some districts, and the land was sometimes over-limed. The work involved in doing it was particularly troublesome and uncomfortable for both men and horses, but recent bacteriological science and the application of it in field practice has shown that a very small dressing (say ten cwt. per acre) of ground quicklime will give better results, if repeated at a shorter interval of years.

There are two reasons for this. First, we find that in the old heavy system the lime "shells" when carted on to the land had to be laid in heaps and allowed to lie till "slaked" by absorbing moisture from the atmosphere before spreading. This was a slow process; and some of the lime, too, absorbed carbonic acid gas from the air and went back to the same state as the original rock. This meant that the lime was no longer "quick" (or in the calcic oxide condition), but really more or less "deadened." Secondly, such a large dose of the dressing actually poisoned the land, and it was sometimes a year or two before the soil properly recovered, for over-liming was quite common. We know now that this "poisoning" was really a case of killing the soil microbes, and thus stopping the development of fertility until these had time to again permeate the soil after the virulence of the lime had abated.

For these reasons, therefore, we have found from repeated actual experience in recent years that the grinding up of the quicklime "shells" in a mill at the works and the application of a small dressing of the same in the "quick" state fulfil all the conditions of chemical and physical action on the soil, and keep the nitrogenous microbes in a healthy "basic" medium.

Liming, however, is most efficiently carried out in more ways than one, and good results are obtained in practical farming by using other dressings than actual quicklime. To properly understand this the chemical changes through which "lime" passes should be studied, and therefore these are set out below :

1. Limestone, chalk, marl—the natural rock form—contain the Carbonate (CaCO_3).

2. When burnt they become the Oxide of Calcium (CaO) or "lime," "quicklime," "lime shells," etc.

3. The above "slaked" with water or moisture from the air become the Hydrate of Lime (CaH_2O_2).

4. Eventually all forms return to the Carbonate state once more, but in a finely powdered condition, by absorbing carbonic acid from the atmosphere.

It will be seen that even when lime is applied to the soil in its oxide or caustic "quick" condition it eventually returns to its original dead carbonate state sooner or later, though in a very fine powder, and, by inference, if the original carbonate rock could be ground sufficiently fine it would give as good results on the land. This has been tried with success in actual practice, and the fact has been established that if limestone or chalk is only ground fine enough it will be quite efficient for most farm purposes.

That powdered limestone is quite efficient is shown by the fact that chalk pure and simple is often put on land. It is quarried out in the wet state and put in heaps on the ground when there is a chance of frost. This splits the lumps into small fragments which can then be spread over the soil. There is a danger of the lumps setting hard, however, and in all the ways of liming land it is desirable to have as fine a division of the material as possible.

Gypsum or sulphate of lime is sometimes applied, though not so often in this country as in the United States. There it is known as "land-plaster" and much used about stables and cowsheds for soaking up the liquid manure, and is then employed in dressing the land.

Besides these methods, liming is sometimes carried out in the form of marling. Marl is clay containing a large proportion of the carbonate of calcium intimately mixed with it, and many geological formations contain such beds. When these were near the surface and easily accessible it was the custom to dig the marl out and spread it over the land. This practice has been discontinued in our days

because of the cost of labour, but in many districts all over the country—in Cheshire, for instance—the old marl and clay pits still remain, forming useful ponds of water in many cases—a relic of the farming of our forefathers.

Another variety of lime much used near large cities is that known as gas-lime. In the purification of lighting-gas from sulphur at the gasworks quick-lime is used, and the latter absorbs the sulphur in the form of sulphide and sulphite of lime. This bye-product is largely used by farmers, and on heavy land it is now a valuable source of lime for the soil. These sulphur compounds gradually become oxidised into sulphate of lime or gypsum, while there is always some oxide and carbonate also in the gas-lime heap. When this material is fresh from the gasworks—especially if of a blue or green colour from the presence of some ferrocyanide compounds—it is a deadly poison to plants, and it must be put on in autumn, or otherwise held over until it has been ameliorated by exposure to the air.

There is a vast difference, which ought to be known to farmers, between the varieties of lime in the market. A “fat” lime is one with a large proportion of pure oxide of calcium, while a “poor” variety is one with a lot of useless silica, etc., in it. Thus the limes produced from chalk, mountain, and other lime-stones are the best, while those from the thin argillaceous deposits are much more inferior ton for ton. These thin, poor “grey” limes are very often the best for builders, because they set like cement—like the Lias lime, but the other—the “white”—is the best for the land.

There is an important deposit of the Magnesian Limestone in the north of England, but it yields lime which is not liked for farming purposes. The excess of magnesia seems to “burn” the land in a way that common lime does not.

IV.—Irrigation

In some of the dry and hot countries of the world irrigation, or watering the land by streams and ditches, is necessary to make crops grow. There are thousands of square miles of fertile lands in India, California, and other countries, which lie absolutely barren until water is brought to them by irrigation. In our country there is no land barren from want of a copious rainfall, but nevertheless there are certain districts in which it pays for various reasons to flood at certain seasons with river water by way of improving them. The meadows that lie alongside the brooks and rivers which drain the

Downs and Salisbury Plain are examples ; the water is highly charged with lime, and this flowing over the grass during certain periods in the winter time helps the growth of the grass and yields an early spring crop. Another case occurs on the banks of the Mersey, where the floods carrying silt are allowed to flow over the meadows for a time, afterwards the sluices are shut and the water kept out during the rest of the year while the grass grows. It is only in cases where the water contains some silt or valuable matter in solution that irrigation is of any use in this country ; the water alone is not much required in ordinary seasons, while of course the work can only be carried out conveniently on the level lands adjoining a stream.

A special form of irrigation is that known as "warping," practised on the level land alongside the rivers that run into the Humber, and the adjoining districts. In this system the tidal water, carrying a tremendous lot of silt, is run over the land as deeply as possible and allowed to deposit its burden. By successive floodings an actually new soil is deposited on the levels, as deep as desired, and thus a new bed of alluvium is laid down artificially. When once the soil is made in this way, however, the water is shut out, and no further "irrigation" takes place.

At one time in this country there was a great belief in water-meadows : the level fields near a brook were laid in regular "beds" with irrigation channels between and the water run on, but these are mostly disused now, for the simple reason that the application of plain water to a field was seldom of any value in our moist climate.

On the other hand, irrigation offers a valuable means of disposing of the sewage of a town, and most towns and even villages are nowadays provided with sewage farms, unless they are near the sea-shore and thus can discharge directly into the sea. The modern treatment of sewage consists in running it through settling tanks, then in a thin stream over various bodies to expose it to the air so as to permit the oxidising bacteria to do their work and really "ferment" the sewage material into a soluble and innocuous condition, though afterwards the effluent water is best run over some land before it is safely got rid of.

Sewage irrigation for the disposal of the liquid refuse of a town is generally a big engineering job, which is quite outside the province of farming in the ordinary sense, but as there is a lot of sewage or liquid manure to get rid of at every farm, some of the points connected with its disposal should be looked into. Usually this material is allowed to discharge itself into the nearest ditch, but in view of

the future development of sanitary regulations some other way will have to be found, probably in the near future, for its disposal.

Hitherto the idea has been to collect it in a tank, pump it into a water cart and spray it over the grass fields. Those who have such tanks at their homesteads have probably followed this plan for a year or two and then given it up as an unmitigated nuisance. The labour difficulty is considerable, for no one cares for such a nasty stinking job, while as it is impossible to keep out a large share of the rainfall of the homestead, there may be a tremendous lot of water to deal with. In time, therefore, the tank becomes merely a settling cess-pool, and the liquid runs into the nearest ditch.

The future arrangement will be to spread this effluent water over the surface of the land, somewhere below the homestead, and there allow it to soak into the ground. It is simply a case of getting rid of the stuff the best way we can, for when regular irrigation is tried, it is found that docks, weeds, and coarse grass spring up so strongly as to spoil the crop.

Loamy and humus soils are the most suitable for irrigation. If the soil is an open, porous sand, the liquid then percolates down too rapidly and reaches the drains before it has had time to purify, and

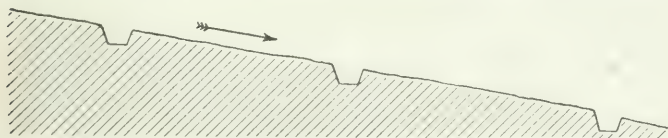


FIG. 8.—CATCHWORK IRRIGATION, SHOWING CONTOUR FURROWS CUT ACROSS THE SLOPE TO CATCH DOWNWARD FLOWING LIQUID MANURE.

the brown juice may reach the ditches just as much as if it were turned in direct. On the other hand, a clay does not allow of sufficient percolation, and the water is liable to flood the surface. With a medium soil, however, there is the proper combination of porosity and retentiveness for the work, but unfortunately we have generally to take the soils as we find them.

Where sewage has to be run on to the surface of a field there is often considerable difficulty and expense in spreading it evenly over the land. The easiest and best way is that known as the catchwork or contour system. The sewage is laid on the top of a field, and *across* the slope small furrows are dug at a perfect level. These form contour ditches, as it were, and must wind about so as to keep the level, and,

at the same time, suit the inequalities of the ground. The liquid flows over the edge of these and spreads about, and is then caught by the next furrow, say twenty feet farther down the slope, and redistributed over the surface again. (*See* Fig. 8.)

When the object is to get rid of the stuff it is remarkable how much an acre of suitable soil will absorb. The furrows must be laid off in two lots, so that they can be worked alternately. The object is to allow of aëration, for one of the essentials is that the soil must have time to run itself dry in order to let the air into the pores so that the "aerobic" microbes may do their work of oxidising and destroying the fæcal matter.

Where sewage irrigation can be carried out for manuring crops the most suitable crops to grow are Italian ryegrass and Timothy grass. If it is intended to cut the crop green, then the ryegrass will be the best, but if it is intended to make hay, the other is better, for sewage-grown ryegrass makes very inferior hay.

V.—Manuring

The specific application of manure to individual crops will be dealt with in a succeeding volume, but it is necessary here to take up the general question of manuring from the soil point of view. It was pointed out in a former chapter that every soil was made up of about twelve chemical bodies, occurring in various proportions in various soils, and that a fertile soil must contain the most of them.

It is found that all our crops and vegetable productions are composed of exactly the same chemical bodies in various proportions, with the one notable exception of the metal aluminium or its oxide alumina—the principal ingredient of the clay in the soil.

Now, every crop that is grown and removed from the field, either by cutting and harvesting or by feeding live stock, which may in turn be sold off the farm, takes with it so many pounds per acre (per annum) of each of those ingredients, and when this process is repeated year after year for a lifetime or a century, the stock of those bodies originally in the soil, and forming a large part of its available material bulk, must be reduced, and eventually a stage would be reached approaching barrenness or sterility.

In actual farming this stage is never reached, because examination has shown that ordinary soils in the first six to eight inches in depth contain fertility enough to grow over a hundred crops, and many things would happen before the first hundred years would expire. On the other hand, however, we sometimes meet with cases where

persistent cropping has so reduced the stock of readily available ingredients as to seriously interfere with the quantity and quality of the following crops. In such a case the land has been "run down," and time must be given for it to replenish itself by the production of some more of its soluble elements by weathering, fallowing, and cultivation, or by directly applying plant food to it from outside.

Again, the continuous application year after year of natural and artificial manures and the consumption on a holding of corn, oil-cake and other concentrated feeding stuffs gradually increases the stock of readily available plant food in the soil, and it gets into good condition with "cumulative fertility." The crop and stock carrying power of the land is thus gradually increased as the time goes on from this "high farming," and a farm becomes more valuable in consequence.

After half a century of legislation it is now settled that the unexhausted value of the manures and feeding stuffs belongs to the man who put it there—the farmer—and an outgoing tenant is entitled to be paid for it. The fixing of the cash value is a difficult task, and will vary according to the nature of the soil, stock, and local customs, but some of the leading agricultural societies have drawn up scales for the guidance of valuers, and the general consensus of opinion is that the fertility left behind from such manuring will last for from two to three years. It will in the case of retentive soils last much longer, but it is necessary to set a limit for practical use.

As a tenant pays rent for the gradual removal of the inherent fertility in small annual portions, it follows in equity that he should not be required to hand over a farm in as good a state manurially as he received it, but to counteract this landlords always specify in their farm agreements that the fertility must be kept up by corresponding dressings of manure, and the leaving tenant can only claim on the "unexhausted" surplus.

The "valuation" at a change of tenancy in these matters is one of the most important episodes in a farmer's life, and all the points connected with it are well worthy of being studied by everyone who has to do with land.

A close enquiry into the question of manuring has revealed the fact that out of the dozen bodies in the soil only about seven are really needed by the plants. Of these there is a superabundance in the case of three or four, and no amount of excessive and prolonged cropping would reduce them to the danger limit. The "exhaustion" of a soil thus reduces itself to the immoderate removal of about four

of the dozen. Those four are nitrogen, phosphoric acid, potash, and lime. In a few exceptional cases magnesia may also be reducible, but probably nineteen times out of twenty the first three only are liable to be depleted. We can see, therefore, that it is necessary to replace these in some way or another, and the whole practice of manuring reduces itself—to put the matter generally—to returning these bodies to the soil. All our commercial varieties of artificial manures, and even such forms as farmyard manure, are merely various forms and compounds of them, and our great and far-reaching manurial experiments are simply a ringing of the changes, as it were, on the different kinds of these bodies.

We can even go a long way further than this. In the section on liming it is shown that lime, marl, and various calcareous compounds are very little required as direct manures entering into the composition of a plant, but that they are valuable and necessary as affecting the soil itself, require to be separately applied, and may be left out of the category of manures.

Again, potash is required in comparatively few cases. The lighter soils are sometimes helped by a dressing of a potash manure ; in heavy soils, however, not only is it not needed, but a dose often does harm to the crop, so that this body may also be left out of the list in the vast majority of cases.

Lastly, we come to the manurial ingredient nitrogen, and its compound—ammonia. In all “prescriptions” for manures there is usually an allowance of nitrate of soda or sulphate of ammonia, bodies useful because of the nitrogen in their composition, while such manures as guano, farmyard manure, and other “organic” manures, are valued largely for the nitrogen they contain in common with the other elements.

The question of nitrogenous manures, however, opens up the wide subject of the nitrogen in the soil and the renovation of it by natural means. Within the last generation it has been demonstrated that the rotting of manure, humus, organic matter, etc., is entirely due to the action of microbes, and that, indeed, many of the natural chemical reactions—or combinations in the soil—are due to germ life. Plants can only take up their nitrogen from the outside in the form of nitrates, and the conversion of the nitrogen in nitrogenous matter into nitrous acid and then into nitric acid is the life-work of several species of microbes in the soil.

As previously pointed out, the soil must contain alkaline or basic substances to take up this acid as formed, and thus lime comes in as the most useful to apply. In this way the nitrogen

actually in the soil, or in the manurial substances applied to the soil, is made available for plant food.

But still another discovery has been made in recent times which has still further altered our ideas regarding nitrogenous manure and the practical application of it. If the roots of the clover, bean, pea, or any other leguminous plant are examined, there will be found nodules or excrescences on them, ranging in size from a grain of sand up to that of a small pea, according to the kind of plant.

Research and experiment have shown that these nodules are the result of the growth of certain microbes inside them. These microbes extract nitrogen from the air in the soil, combine it into some compound or other, and then pass it into the roots of the leguminous plant which forms the "host." This partnership or interdependence of two plants is called "symbiotism," and in practice it means that leguminous plants of all kinds do not require nitrogenous manuring—may indeed be injured by such—but that a supply of suitable microbes in the soil is more necessary, and they may require to be added to get good results in growing leguminous crops.

These facts have now influenced practical farming so far that "cultures" of the suitable varieties of microbes are sold commercially, and are applied to the seed—or even direct to the soil—of the crop about to be grown, and in many cases do more good than actual manuring.

But the matter does not stop here, for by analogy we might expect that other plants besides those of the leguminous order would have microbic helpers as well. That this is so has been proved by recent experiments, and microscopic bodies have been isolated in a suitable culture that promotes the growth of cereals in the same way.

It is therefore now safe to say that all our species of crops will sooner or later be found to be controlled as regards their growth by the presence or absence of their own special microbes in the soil. The use of a "culture" is likely to be more useful on poor soil than on rich, for the latter is very likely to be well supplied with these organisms already, but the point is that they act as intermediaries between the plant and its manurial food, and many cases of barrenness or failure of a crop are now traced to deficiencies in this line.

All this points to the fact that direct nitrogenous manuring is not really so necessary as we once thought. If leguminous plants are grown at frequent intervals, and if the soil is inoculated with

the proper culture (if the suitable microbes are not present in it) where poverty or barrenness is apparent, then the nitrogen gets replenished in a natural way from time to time, and none need be supplied in a manure excepting in special cases.

Summing up all these facts we arrive at the conclusion that the food of plants exists in superabundance in most soils, or can be added by a natural and inexpensive system of replenishment, with the exception of the one ingredient of phosphoric acid. We are, therefore, now satisfied that possibly in nine cases out of ten an application of some one or other of the many forms of phosphates of lime is all that is required to keep up the fertility of land under a proper system of cropping. It is the one ingredient that is universally deficient in the soil, that is not added by the ordinary farmyard dung of the farm in sufficient quantity, and that cannot be developed or extracted from anywhere by any system of cropping or treatment, and must be returned by extraneous manuring.

We must now take a look at the changes produced in the soil by manuring from other points of view. The most common and natural manure is farmyard dung, and, of course, as much of it as possible ought to be made on the farm. When it is necessary to supplement this, then artificials are cheaper to purchase than dung, unless there is some special reason for doing otherwise.

One of these special reasons is the value of dung and other bulky organic manures, like composts, in improving the texture of the soil, in making it more friable, porous, and open with clay, and "stiffening" it in the case of sandy soils. It, at the same time, supplies extra humus, which improves the power of the soil for holding capillary water, for humus of all the Proximate Constituents is the best for this purpose, and it does not puddle if worked while wet.

Another good point in favour of dung is that repeated applications of it tend to darken the colour of the soil and thus raise the temperature from the extra absorption of the sun's rays, while the actual fermentation of the dung (microbic life-action) also raises the temperature temporarily by a few degrees.

As previously stated, when the home supply of dung runs out it is doubtful if it would not be cheaper to expend money in purchasing phosphatic manures, but the production of bulky organic manures can be greatly aided by sowing such crops as mustard, rape, clover, etc., and ploughing these in. By this means a large bulk of rich humus is eventually added to the soil when these decay, and thus the characteristics of the soil are improved very much.

On the lighter classes of soil, or on any soil in the drier districts,

sheep-folding is largely practised, partly from its convenience in using up a growing crop and fattening off the sheep, and partly from its manurial results. The droppings of the animals are evenly and directly spread on the surface, and when lightly ploughed in add very much to the organic matter in the soil and to the store of fertility. Many forage, catch, and root crops are grown for this purpose, so that the texture, retentiveness, and fertility of the soil are all improved at the least cost and labour, while the animals are fed and fattened off as well.

CHAPTER V.—THE TILLAGE OF THE SOIL

TILLAGE is the last subject to be discussed in connection with the soil. Tillage may be defined as the making of Tilth, and the tillage operations comprise the regular and entire work of a farm for three-fourths of the year.

All the other things in connection with the soil—its nature, the changes that take place in it, its improvement—are auxiliary from a farming point of view to the “working” of the land.

The varieties of work carried on in tillage operations are many and varied, but they may be included under (1) Ploughing, (2) Cultivating, (3) Harrowing, and (4) Rolling.

I.—Ploughing

The first operation carried out in the way of ordinary cultivation is that of ploughing. In a state of nature, land is always in grass or pasture; even where a wood or a coppice exists, there will be grass of some kind growing on the ground, if not too completely smothered out, and under this condition the removal of the overhead foliage would soon be followed by a growth of vegetation of some kind on the ground below. To turn this grass land into tillage the first work is ploughing, and again, on land already in cultivation, on the removal of a crop, the preparation for the next crop, in nine cases out of ten, begins also with ploughing. The technical points connected with ploughs and ploughing will be discussed later on, and therefore at this point it is only desirable to investigate the use and effects of ploughing on the soil. The operation practically amounts to this—that a wad of soil ten inches wide and seven inches deep is cut off the edge of the solid land, turned on its edge over a third of a circle, and left partially upside down at an angle of forty-five degrees. In the old style of ploughing it was desired to turn this wad or furrow-slice without breaking or cracking it, and to leave the nicks or seams between successive slices as deep and clean cut as possible. Nowadays, with the improved “digging” ploughs, the slice is very much pulverised and broken up, and turned more or less upside down, with the surface rubbish completely buried. That

this is the best kind of work to do will be shown immediately. The objects of ploughing are various.

The principal one is to bury the surface herbage so as to destroy the wild growths in order that cultivated plants may take their place. If a fringe of grass or herbage is shown between the furrow-slices, then the work has not been properly done, and a different plough or one with a skim-coulter should be used.

The second object is to pulverise the soil. This has only been recognised within the last generation or so, since the introduction of the American chilled-steel "digging" breasts on ploughs, for in the older days, and even yet with backward farmers, the old style with long sloping breasts was employed, whereby the furrow-slice was turned over whole. The idea now is to crush the earth on itself so as to break it up thoroughly, even on stiffish soil, and spread the crumbly material loosely over.

In other words, the act of ploughing nowadays largely includes that of cultivating, and the subsequent work of the cultivator and the harrow is very much reduced. At the present time complete inversion of the furrow-slice is desired, as it buries the rubbish best and leaves the surface in the best friable condition.

By pulverising the soil is opened up to the action of the air, frost, rain, etc., by which the texture, the physical constituents, the chemical combinations, and the general conditions of fertility are improved: the soil, as it were, is helped to put its fertility into an accessible form.

Another important object of ploughing is to make a good seed-bed. The native wild plants of the soil will take root and thrive without any cultivation, but the more delicate cultivated crops require genial conditions in the germinating and seedling state. It therefore follows that all the growing grass or rubbish on the surface should be buried completely, so as to give the new plant a clear start, while the pulverising and subsequent mellowing of the turned-up earth gives the seed a better chance to germinate and sprout in a healthy way.

During the whole life of a cultivated plant the roots continue to grow and ramify through the soil, and thus anything that tends to make it more tilthy is a direct benefit to them. The wedge-like power of a growing root is very great, but when the soil is loosened to begin with it allows of an easier passage, and a more ready access to the plant food. In this way as much as in any other tillage stimulates growth.

As the roots of the cultivated crops very often go no deeper than

the ploughing, it follows that as a general rule the work should be done as deeply as possible. The loosening of the soil helps the surface drainage by letting the rain percolate downwards very quickly, and thus in a time of extra wet will tend to keep the surface dry. The depth, in any case, should be sufficient to prevent the harrows from tearing up the refuse to the top again, while the more deeply it is buried the more quickly it will die and decay.

If a "plough-pan" has been formed by the constant passage of the plough at the same depth year after year, by which a hardened or pacted-up layer has been formed, then this ought to be broken up by going a little deeper.

Again, the tendency of some of the elements of fertility is to get washed downwards by the percolation of the rainwater more than capillarity can equalise, and so the turning of the lower layer on to the top aids capillarity and keeps manurial matter near the surface.

The turning over of a furrow-slice and leaving the top five to seven inches of soil in a loose, friable condition is equivalent to forming a "mulch" of it. Gardeners at the beginning of winter very often put a lot of rough manure round their plants on the surface of the ground for several reasons: it keeps in the moisture when the dry weather comes, it keeps the cold of the air from readily penetrating downwards, and it keeps in the heat already in the soil. The bed formed by a succession of furrow-slices all over a ploughed field acts in exactly the same way, and forms a sort of mulch to the soil below, and indirectly benefits the plants.

In order to get the full benefit of the fertilising effects of the weather, the ploughing should generally be done as early in autumn as possible. Some farmers, indeed, try to have all their ordinary ploughing done before Christmas or the New Year time, and if the soil is of the stiffer class it is very desirable to do so. On the other hand, on the light sandy varieties the work may be postponed with benefit, because the weathering is not so much needed to make it friable, while the soil is more liable to lose its goodness by leaching—points which must all be taken into consideration.

In practice, however, the weather usually rules the whole thing. During hard frost it is impossible to plough, of course, while during continuous wet weather it is not desirable, even if it were possible, for the men and their teams to work outside.

1. *Bare-fallowing*.—Throughout the southern half of England, and to a smaller extent in other parts of the British Islands, the system called BARE-FALLOWING is practised. This practically amounts

to ploughing the land repeatedly and otherwise cultivating it during the whole of a summer without growing any crop.

There may be from three to five ploughings of the same land over and over again, with a corresponding number of harrowings, rollings, etc., so that the soil may be gone over from eight to twelve times during the course of a summer in one way or another—the last ploughing just finishing up in the autumn in time to put the ground into shape as regards ridges (or lands) and furrows for an autumn-sown crop—nearly always wheat.

The principal object of a bare-fallow is to clear the land of weeds : if the land is put into a “fallow crop” like roots of some sort, it takes an enormous lot of work in the shape of singling out, weeding, hand-hoeing, etc., while if the land is kept perfectly bare, then the work can be done in a wholesale manner by horse (or other) power, and the expensive manual labour done away with.

Two conditions, however, are required to make it necessary or desirable to fallow the land : a dry climate and a stiff soil. If the climate is wet, bare-fallowing of a stiff soil will not be carried on satisfactorily ; if the soil is light, bare-fallowing is not so necessary, because root working is more easily carried out on a “turnip soil.” These two conditions explain the fact that most of the fallow farming is confined to the stiffer soils in the southern half of England.

It may be thought at first sight that ploughing the same land from three to five times over during the course of a summer is preposterous, and that the use of a cultivator might do the thing more economically, but years of experience have shown that on stiff land the plough does the work best : cultivation only stirs the clods, while ploughing turns them upside down, pulverises them better, and kills the weeds much more quickly. If the fallow is very cloddy it is sometimes impossible to work a cultivator.

Of course, cleaning the soil is not the only object in bare-fallowing ; the land gets a rest for a year at intervals (every seventh year in Mosaic times), and the nitrification and weathering allow of an accumulation of ready fertility which prepares the soil for an extra good crop to follow. Again, the exceptional amount of stirring and mixing of the soil that takes place causes a greater amount of this fertility to be set free by the stimulation of the various chemical reactions and the modification of the texture of the soil. The total result, therefore, is to have the soil thoroughly cleaned of weeds, to have it mellowed and improved in texture, to give it a rest, and to allow of the accumulation of the soluble fertile ingredients.

A field thus treated will yield better and cleaner crops for several years afterwards, and pay well for the work. The introduction of fallow crops more than a century ago, in the shape of mangolds, swedes, turnips, etc., tended to largely reduce the practice of bare-fallowing, and it is now only followed as a regular practice on the heavier soils in the drier districts, but in these cases it is a commendable practice.

So much good is done to the soil by bare-fallowing, that many years ago, a clergyman (the Rev. Mr. Smith) at Lois Weedon, in Northamptonshire, inaugurated a system of alternate fallow and wheat cropping, which he carried on for over thirty years with perfect success. The land was laid up into the usual narrow "stetches," and each alternate one was summer-fallowed, and the other alternate ones cropped with wheat—changing about each year. Thus, practically half the field only was in wheat and half in fallow, yet the wheat yield totalled over the whole better than the usual crop of the neighbourhood. A system like this, of course, depended wholly on the "inherent capability" of the soil, and it could have only succeeded where the soil was stiffish and of a fertile kind—for the system would have failed on a light, poor soil or in a wet district; but the point is, that a perfect and continuous bare-fallowing was the basis of the whole practice.

It must be emphasised that there is another reason why fallowing succeeds best in a dry district; there is no waste of fertility from leaching. As already shown, a growing crop helps very much to retain plant food in the soil, and if fallowing—which means complete killing out of all vegetation—is followed when there is much rain then there is an extra waste of this plant food. On the other hand, a bare-fallow is usually sown with winter wheat, so that there is a crop ready to absorb the nitrates and other manurial bodies before the rains of winter come.

2. *Subsoiling*—This process is quite a different matter from ordinary ploughing, and on certain soils may do a vast amount of good. It may be done by having one plough of a special kind to follow another in the furrow made by the first, and thus stir up the bottom several inches down without bringing it up to the top.

Another method is to have a large tine fastened on to the beam of the ordinary plough in front of the mouldboard (*see* Fig. 9), so that the bottom of the furrow is ripped up as deeply as possible, and then the new furrow-slice turned over on the top of it. The steam cultivator, again, may be set deep enough so as to penetrate

through the soil into the subsoil, and thus break it open. The point to be aimed at is to simply stir up and pulverise the subsoil and leave it below the soil in the original relative positions, so that there is no admixture or bringing the possibly poisonous stuff to the top. The benefit to the land is due to the loosening of the subsoil so as to let the water down more freely, and also the roots of the crops if they find it suitable; to the breaking up of the "pan" if one has formed; and to the aeration and ventilation of the whole body, whereby oxidation and other improving chemical reactions are promoted.

The poisonous bodies likely to be present are such compounds

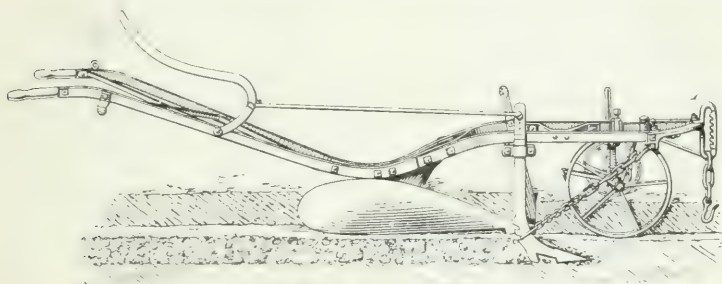


FIG. 9.—PLOUGH, WITH SUBSOILER ATTACHED, BY WHICH THE BOTTOM OF THE FURROW IS RIPPED UP AND IMMEDIATELY COVERED BY THE FURROW-SLICE.

as sulphide of iron, sulphuretted hydrogen, humic and other earthy acids. These are inimical to plant life until oxidised or otherwise modified, and if too much of the subsoil containing these is brought to the top it may take years to convert it into soil good enough for crops.

Subsoiling in this way never does any harm, as deep ploughing might do, but on the other hand it may do no appreciable good. Where the soil is gravelly or sandy, or even loamy, it is very likely that the deeper soil and subsoil will already be so open and porous in their texture that to stir them up would only be throwing away money.

On the heavier and stiffer class of soils, however, the operation is of the greatest value, more particularly in assisting the downward percolation of water, and thus preventing the waterlogging and

souring of the land in wet weather, at the same time assisting the general farming of it.

Subsoiling, however, is very expensive work. The ordinary plough with a subsoiler attached will take four horses and two men to handle it, and not go very deep at that; where one plough is followed by another in the same furrow (known as "trench-ploughing") it may take six or seven horses and three men, and the field will be gone over very slowly; while with the steam cultivator there has never been much of a success made in practice, probably because the drivers were too afraid of bursting their engines by letting the tines go deep enough into the ground.

It is perhaps in the matter of assisting the downward percolation of the water that the deepening of the staple and subsoil does most good. On the stiffer class of soils in wet weather the soil very soon fills up with water which cannot get downwards, and it not only kills any crop growing there but begins to wash over the surface, finding its way into the nearest waterfurrow and ditch, and carrying with it much of the soluble fertility of the soil or of any manure present.

Now, the stirring of the deeper layers has the effect of aiding the downward passage of the water to the drains below, and thus while leaving the top dry and open keeps the fertility in the soil.

II.—Cultivating

Cultivation is a general term applied to many different kinds of work, all of which have for their object the pulverising of the soil, the mixing up of the ingredients, the opening up of the whole to the action of the weather, the eradication of weeds, and, generally, the melioration of the soil to make it more suitable for plant growth. It usually follows ploughing, and in some form or another constitutes a large share of the tillage which goes to make tilth.

Work of this nature is done with a special implement, called a cultivator or grubber. It is pretty well conceded now that rigid tines on these cultivators, with spring sockets or settings, is the best form. The action of the spring yields a little to obstructions, allows of a certain amount of vibration or play of the tine, and thus improves the work and enables the shares, or cutting parts, to keep clearer of weeds as they move along. (*See* Fig. 10.)

The work of the cultivator does not always follow the plough, however, for in districts where steam cultivation is common, this

work is usually carried out on the untouched stubble land, and in dry weather when the ordinary plough probably could not touch it. Cultivating with the huge steam implement after harvest, or after a crop has been taken off in summer time, is one of the most efficient ways of breaking up the soil, mixing it, rooting up the weeds, and killing all the surface rubbish, so that a "half-fallow"

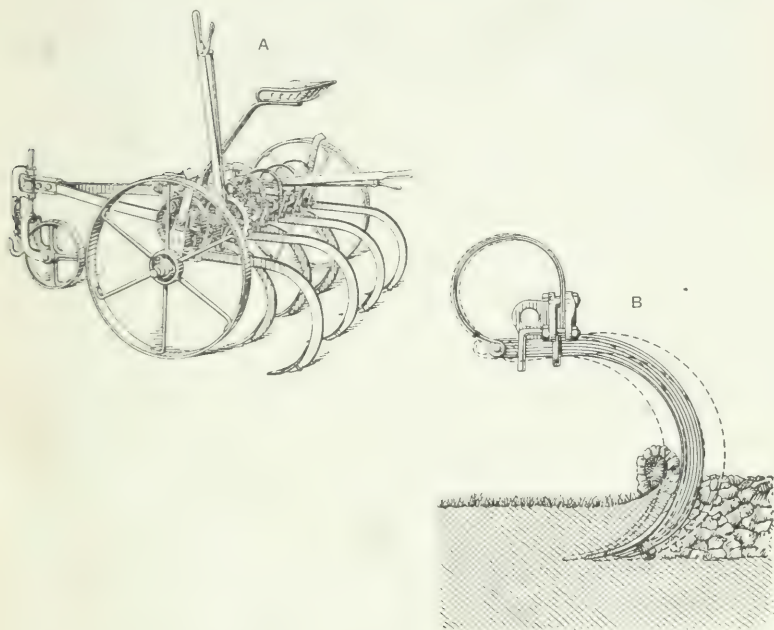


FIG. 10. —ROYAL AGRICULTURAL SOCIETY'S FIRST PRIZE CULTIVATOR. A. TWO-HORSE SIZE. B. VIBRATING ACTION OF TINE WITH SPRING SETTING.

made this way is a very good thing, and allows of the growth of a crop of some sort during the previous part of the same summer.

It is, indeed, with the cultivator that steam-power has been most successful. The natural depth of the soil limits the depth of

ploughing to, say, seven inches, and the giant strength of steam is wasted in doing work that ordinary horse-power can accomplish more cheaply. On the other hand, as cultivation consists in only ripping up the soil and stirring it, one may go as deep as possible with the greatest benefit ; indeed, the trouble in practical work is that the workmen will not go deep enough. They are generally paid by the acre, and prefer, if not looked after, to skim along at the ordinary plough-depth, while when the grubber is sunk into the solid subsoil it often stops the engines.

There is no doubt that if the steam-power is sufficiently strong, and the tines set deep enough, this would be the best way to break up the soil "pan," stir up the subsoil, and loosen and mix the bulk in a way that would be a permanent improvement, besides doing the ordinary fallowing work.

The ordinary cultivator is an implement drawn by three or four horses, and taking a width of from five to seven feet at a time—allowing three tines or teeth to every horse. The depth accomplished is never beyond plough depth, or say six inches, and is generally less excepting on the lighter soils.

Indeed, where the soil has been ploughed or stirred once to a good depth there is less necessity for going deep with the cultivator afterwards, and sometimes three to four inches are quite sufficient. A good rule is to plough deeply enough to completely bury the surface rubbish and then cultivate lightly enough so as not to bring the rubbish to the top again, unless it is intended to make a regular summer fallow. Scarifying, that is cultivating only two to three inches deep in dry weather, increases the mulching power of the soil, and preserves more of the capillary water below from evaporation.

A cultivator is a large-tined implement, differing chiefly in size from a barrow. There is an endless variety of forms, and between these two extremes there are any amount of intermediate kinds, some of which will be examined when we discuss the Equipment of the Farm.

Cultivation on the smallest scale is hand-hoeing. In a garden, or where small culture is followed, the soil will first be turned over with a spade—work which the "digging-plough" imitates—and then the cultivation afterwards is done by hand-hoe. On a slightly larger scale we have the horse-hoe, used between the rows of plants, with the hand-tool as an adjunct.

Hand-hoeing is of course one of the most expensive labour items on the farm, but we cannot get on without it. In the cultivation of root crops—which require the plants to be "singled" out separately

—the hand-hoe is necessary, and indeed the growth of all our farm crops in regular rows necessitates cleaning and surface cultivating by this hand implement.

Cultivation in the proper sense of the term cannot, of course, be carried on in the winter time—only ploughing—and the work done in the other seasons depends very much on circumstances. Spring cultivation will do very well in districts where the rainfall is plentiful, but where the summers are dry it wastes the moisture to stir up the soil deeply in the drying spring winds, and, therefore, in such cases autumn cultivation must be carried on: the land ploughed and worked about after harvest as much as possible, and then ridged up or left rough for the winter.

III.—Harrowing

The harrow is simply a surface cultivator. The plough first moves the soil in more or less solid pieces, the cultivator breaks these up, mixes and stirs them about, and the harrow completes the work by comminuting and levelling the surface. The original and primary use of the harrow was, of course, to simply cover in the seed. The seed was scattered by hand on the top of the ploughed or cultivated land, and the harrow (the branch of a tree in ancient times, was dragged over it to level down the rough parts and cover the seed.

Nowadays there is every conceivable form of harrow, and some implements, as before stated, are intermediates between a harrow and cultivator, while every kind of cultivating work can be done by them.

The typical harrow is used simply for surface cultivation. It breaks up the lumps on the surface, levels them down, and leaves the soil comparatively smooth and even, and puts the finishing touches to the cultivation, as it were. As with the cultivator, the best modern varieties are the "spring-tooth" forms with adjusting handles. The spring-tooth is, of course, made of steel, and in work it dances and vibrates about in a way that thoroughly shakes up the soil and prevents the clogging of its own teeth with rubbish. The clogging of the harrow-teeth is one of the drawbacks of working on the soil if wet or weedy, and the modern "spring-tooth" form obviates this difficulty.

Some harrows are really cultivators, such as the "drag" harrow, while even some of those that do not go quite so far in this line

are more than mere surface smoothers. Thus, the disc-harrow, the acme-harrow, the Norwegian harrow, and the "duck-foot" harrow all do more than ordinary work, and really stir and mix the top layer from the top in contra-distinction to the cultivator, which more or less rips up from below. It is in regard to this difference of working that the chief distinction between a cultivator and a harrow lies. The tine or tooth of a cultivator is always curved forward, so that the point or share on it grubs up from below, whereas, a harrow-tine enters the soil more or less perpendicularly and simply scratches or stirs from the top.

When the digging plough with modern pulverising mould-board is at work, the soil is often so crumbled and level-spread that further work is unnecessary, and the seed may be drilled in on the same without any additional work, excepting one stroke or so just to smooth off for a finish.

As a rule, a good deal of harrowing is desirable. It makes the surface finer and better mixed; it kills any seedling weeds by uprooting them; it breaks the surface cap which is apt to set after heavy rain; if not overdone it covers in the seed better; and it forms a fine surface mulch in dry weather.

Like many other things there is a time to do it and a time to leave off. There is no use in trying it when the land is wet—if it is stiffish soil at least—for it would only puddle the soil to do so, and the horses' feet would tend to poach it. Then, as harrowing is generally done in connection with ploughing, cultivating, or seeding, it must be done when these other processes are being carried out properly.

IV.—Rolling

At its first development Rolling consisted of simply smoothing the ground. No matter how well the state of tilth of the soil, the harrow leaves a certain amount of roughness behind it, while on stony or gravelly soil a lot of stones will be left loose upon the top. Rolling flattens these all down, and leaves the field well suited to the work of reaping or other harvesting of the crops.

In our time, however, it has been found that certain other results are obtained by pressing the soil. While a good state of tilth is desirable it is quite possible to have the particles of soil too loose and open, and a certain amount of firmness is necessary to get the seed into proper contact with the particles and moisture of the soil and the plant food.

Furthermore, in a dry climate, the touching of the particles promotes capillarity, and thus the crop may be helped to sustain itself through a drought with the moisture that rises to the roots from below, though the top layer may be absolutely dry.

But rolling has certain other physical influences on the soil. While promoting the flow of capillary water upwards, it also at the same time promotes evaporation, so that while the top soil has more water the under soil as a whole is losing a considerable quantity. For germinating purposes, however, this is what is desired. It may be often noticed that seeds of all kinds sprout most quickly on head-lands and where the ground has been trampled. This is due to the fact that the moisture below comes more readily to the top where the ground has been pressed, and thus the seed comes into closer and quicker contact with the damp and sprouts more promptly.

For this reason also, small seeds, such as grasses and clovers, are often sown on a rolled surface, and then harrowed in afterwards: the soil is broken finer and closes in better about them.

The smoothing of the top of the soil by rolling promotes wind velocity; the wind next the ground may go at double the speed on a smooth field to what it will on a cloddy or rough one, and thus the amount of evaporation is still further increased.

On the soil temperature the rolling of the land has a marked effect, at any rate in the early stages after the work is done. At one and a half inches below the surface it may be 10° Fah. warmer than in the same soil not rolled, and at three inches it has been found 6.5° higher. This is pretty much due to the superior conductive power of the firm soil for the sun's heat as against the loose unrolled part. The loose soil acts as a blanket to keep out the heat, but conversely it tends to retain the heat that is already in the soil, and thus at night or during cloudy weather when there is no sunshine the unrolled land may be best. On an average, however, rolled land is about 3° Fah. warmer than when left loose and rough.

The pressure of the roller is felt from five inches to twenty-four inches downwards, according to the weight of the roller and the nature and state of the soil. A heavy roller should be used—any weight from ten to fifteen cwt. is desirable—and the work with it should not be too quickly hurried over, so as to give time for the pressure to act. The barrel of the implement should be of large diameter—thirty to thirty-six inches—so as to make the draught easy in proportion to the weight.

It is obvious, therefore, that the benefits to be obtained by

rolling are discounted by certain disadvantages, and the point arises if it were not possible to partly counteract those disadvantages. In a dry season the waste of water from a smooth surface may be enormous, and therefore, after rolling, great advantage is obtained by running a light harrow over the ground in order to again ruffle up the surface. By this means the consolidation of the lower layers is obtained for germination and water-supply purposes, while the upper layer forms a loose cover to keep the moisture in.

Gardeners tread down their seed beds very firmly, but take care to loosen and crumble the top afterwards, and to keep it so by subsequently hoeing and raking. We want to apply the same principles to field-work. So much is this the case, that in the dry southern counties rolling of the root crops is very thoroughly and repeatedly done in order to bring the moisture from below and to get the soil close in to the seed or rootlets; afterwards, there is horse and hand hoeing in abundance to keep the top loose while killing off the weeds. Land should, of course, be rolled when dry to prevent pasting up of the pores from the compression, but there is little fear of the work being done while wet, because the roller would clog up in the first few yards if the ground is the least damp on the surface.

A student may have a difficulty in understanding how it is that we use all manner of implements to stir up and loosen the particles of the soil, and do certain other things—such as dressing with a lot of dung—to make it more friable, and then deliberately go and squeeze it down tight again. The explanation is that when the soil has been ripped up by the cultivating implements it is apt to be left too full of actual fissures and air spaces, and the particles must be made to touch again, but the soil once having been separated no amount of rolling will bring about entire cohesion.

The question of the use of smooth versus ribbed or toothed rollers does not seem to have been thrashed out as well as we would like. All the facts before stated apply to flat or smooth rollers, but in England, at least, the use of various other kinds is common. With ribbed rollers there is a line of compression and a line of loose soil left in alternate three-inch strips made by the flutings of the ribs. It follows, therefore, that many of the disadvantages from wind velocity, want of a mulch, and so on are obviated by the use of rollers of this description. This is borne out in practice by the fact that such rollers are mostly used in the drier districts of England.

The method and results of using a roller are indeed very much

controlled by the rainfall. In the wet northern and western districts, rolling once with a smooth roller is done for the purpose only of smoothing the land and pressing stones and clods down so that with (say) corn crops the afterwork may be expedited, and no question of capillarity, evaporation, germination, etc., ever enters a farmer's head : there is sufficient moisture and to spare. But in the southern and eastern counties, where rain is scarce, everything has to be done to conserve the moisture in the soil, and the rolling done and the kind of roller used should be the best for this purpose.

Conclusion

We have now seen in a general way, without going into very much detail, what a complicated thing the soil is, how the surroundings of a farm influence it, and how we may improve and cultivate it.

The study of the soil has been vastly extended during the last ten years or so, and we understand many things now that were a puzzle to our fathers. These results of recent research are being applied to the practical management of the soil in a way undreamt of a few years ago. As time goes on this will be done to a still greater degree, and farmers will more and more utilise the discoveries of science to the working of the land.

A few words may be given, by way of conclusion, in the shape of advice to a farmer inspecting farms as a preliminary to renting one. A sitting tenant has probably found out to his cost by experience all the capabilities and drawbacks of his farm, but a man going into a new district can find out many things in advance if he knows what to look for, and uses his eyes.

A slight knowledge of geology will tell him if he is likely to find sand, loam, clay, marl, or alluvium as the prevailing soil, or if the farm is on an uncultivable hill. A look at the predominating trees will corroborate his ideas of the nature of the soil (and subsoil also) : if the trees stand plumb it is not a stormy district, but if they grow lopsided then the corn crops will get blown over also and "lodged" by the strong winds before harvest.

If there are large woods adjacent, then game and other vermin are liable to be too plentiful ; only just enough trees for shelter is more desirable.

Other things to note are the condition, texture, depth, colour, etc., of the soil, while if the inspection is made when the crops are

growing the best indication of its capabilities is obtained. The efficiency of the drainage, the water supply, the exposure and shelter of the farm and homestead, the steepness or levelness of the fields, the prevailing weeds among the crops, and so on, with a host of other points raised in the previous pages, are matters to be seen to.

There are many things that go to influence the value of a farm besides the characteristics of the soil—such as buildings, markets, labour-supply, etc., which we shall discuss in the succeeding volumes of this series—but the more notice taken of the above points, and others of the same nature, the truer notion will a farmer get of the value of the farm under inspection, and thus save himself much possible expense and loss in the future.

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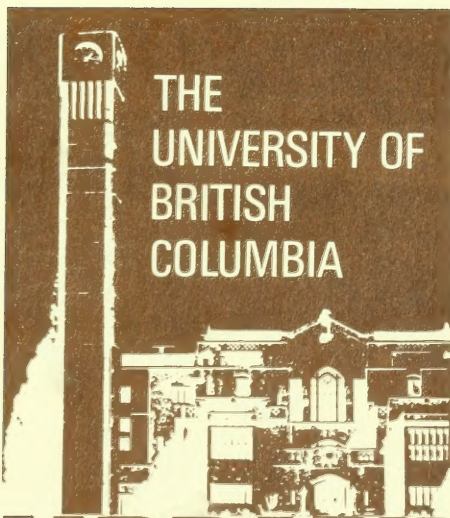
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